SA-75M Dvina
(SA-2F Guideline)
Medium Range Surface to Air Missile System
Simulator Documentation



Version: 1

Contents



Interior of UA cabin of 77th missile battalion defending Hanoi in December 1972, when it shot down four B-52s.

Historical Background

In 1953, after the successful fielding the first Soviet SAM system the S-25 Berkut (SA-1 Guild), the Counsel of the Soviet Union is decided on the development of the follow-up systems.

The prohibitive cost of the fixed multichannel S-25 “Moscow” system initiated the development of two new different SAMs.

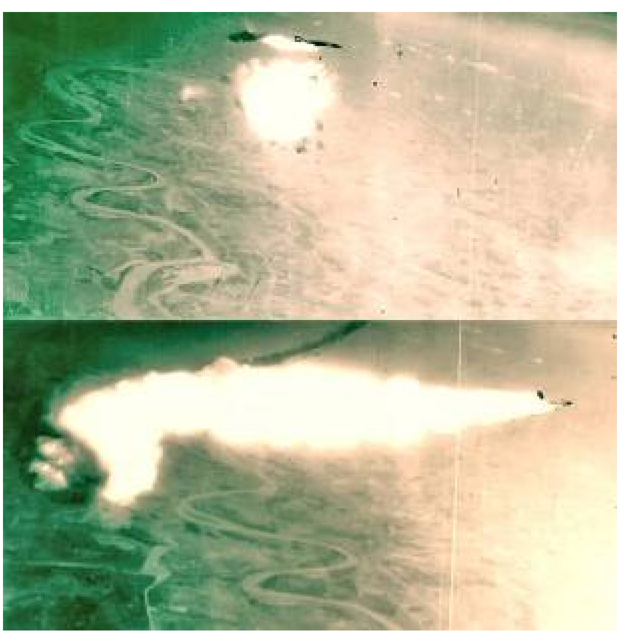
Leningrad (as the second most important city) was planned to be defended by the fixed, multichannel S-50 Dal (SA-5 Griffon) system, while all the other cities by the cheaper, moveable, single channel S-75 (SA-2) family.

Lavochkin OKB-301 was appointed to design the fixed multichannel S-50 Dal "Leningrad" system, while the tougher task of designing a cheap - towed SAM system was given to Raspeltin’s KB-1, the successful designer of the S-25 Berkut (SA-1 Guild).

The "75" design called for a SAM system of 29km effective range, and 20km altitude, working in the 6cm frequency band. When this ran into problems, parallel development on a 10cm system was started.

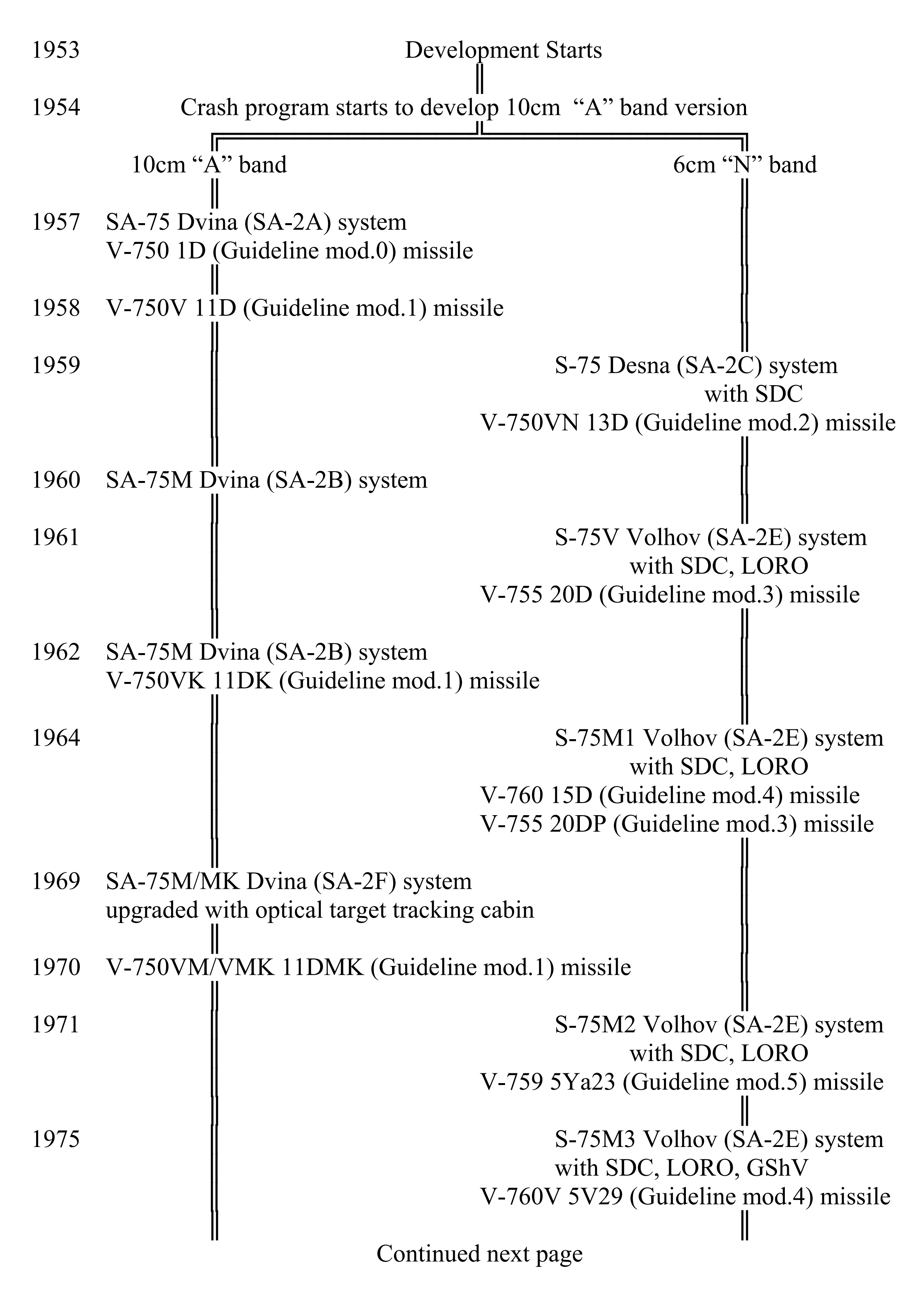


A.A. Raspeltin

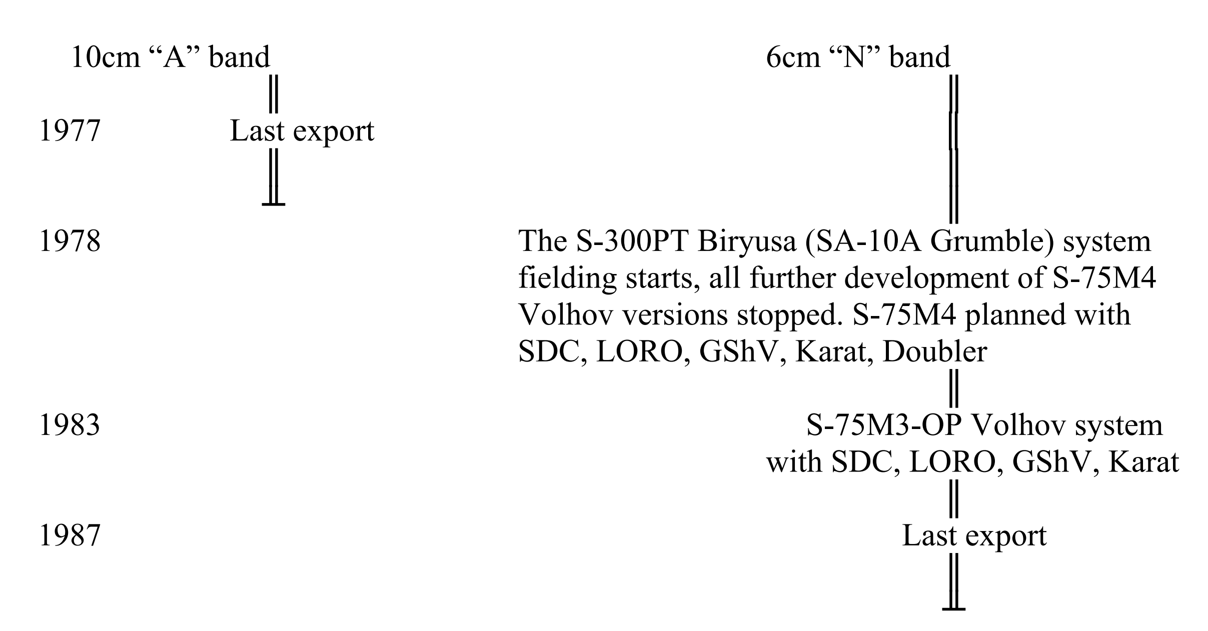


F-4 hit over Hanoi with V-750V 11D missile

The Family Tree and timeline of the “75” System development

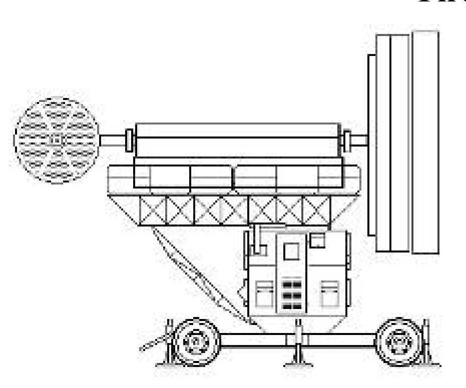


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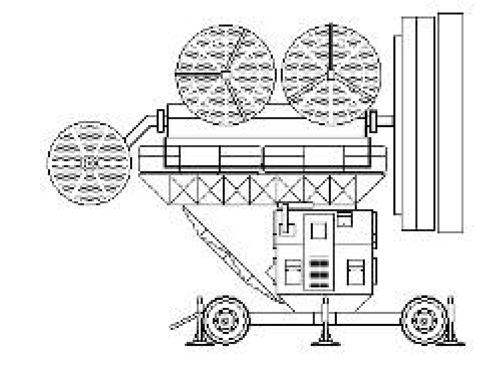


1988, The S-300PMU Volhov-M6 (SA-10B Grumble) system becomes available for export. The Volhov-M6 name was selected to confuse western intelligence.

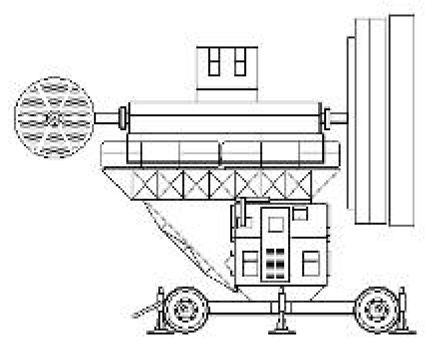
Fire Control Radars



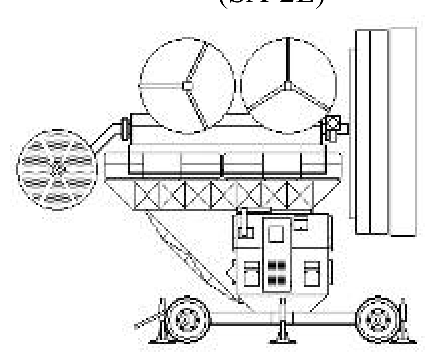
SA-75 Dvina, SA-75M/MK Dvina, S-75 Desna
(SA-2A, SA-2B, SA-2C)



S-75V/M1/M2 Volhov
(SA-2E)



SA-75M/MK Dvina
(SA-2F)



S-75M3-OP Volhov
(SA-2E)

SA-75 Dvina “five van” (SA-2A) with V-750 1D (Guideline mod.0) and 750V 11D (Guideline mod.1)

In 1954 it become clear that the new 6cm wavelength microwave parts had severe production delays. In response, a crash program was started using the old 10cm wavelength ("A" band in the Soviet Union) microwave parts of the S-25 Berkut (SA-1) system. During 1957, the first 10cm wavelength **SA-75 Dvina “five van” (SA-2A)** system was fielded in the Soviet Union. The five vans were: PA – fire control radar; U – fire control cabin; I – indicator cabin; K3 – instrument cabin; K5 – diesel generator and K6 – power distribution cabin.



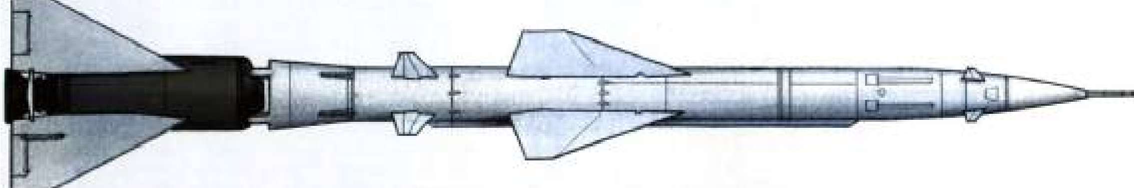
With **1D V-750** missile

Maximum target speed:
1500km/h (420m/s, Mach1.5)
Target altitude: 3-20km
Maximum Range: 30km

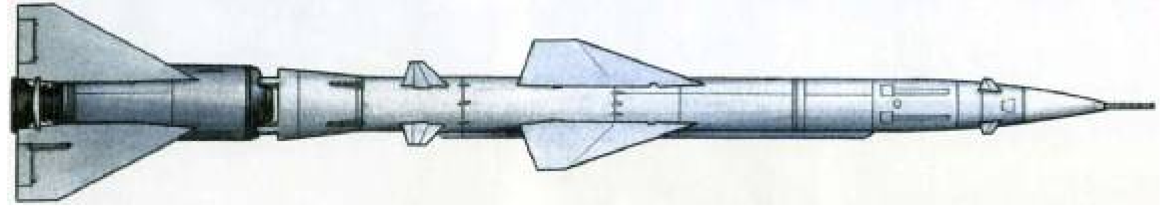
With **11D V-750V** missile

Target maximum altitude increased to: 27km
Target maximum Range increased to: 34km

The **V-750 1D (Guideline mod.0)** missile:



As the CIA's U-2 spy-plane started its regular flights over the Soviet Union only few thousand meters above the maximum effective altitude of the V-750 1D missile, again a crash program started. The thrust of the second stage was increased and the **V-750V 11D (Guideline mod.1)** resulted, fielded in 1958, with increased altitude and range capability.



This system was exported only in small numbers:
China 1958-3 operational +1 training system, 1959-2 operational systems
Albania, Bulgaria, Hungary, DDR, Poland, Romania, Czechoslovakia (all in 1959 and each with 1 operational +1 training system)

SA-75M Dvina "three van" (SA-2B) with V-750V 11D (Guideline mod.1)

Further optimization of the SA-75 Dvina (SA-2A) led to the reduction of the number of the towed vans. This system was called **SA-75M Dvina "three van" (SA-2B)**. The "Three" vans were for: PAA – fire control radar; UA – fire control cabin; AA – instrument (computer) cabin and RMA – power distribution cabin with diesel generators.

Maximum target speed was increased to: 1900km/h (520m/s, Mach1.85)

The Dvina was exported from 1960, in huge numbers with the **V-750V 11D (Guideline mod.1)** missile. Systems exported to the Warsaw Pact were designated SA-75M .

Bulgaria	1960-3, 1961-5, 1962-6
Czechoslovakia	1960-3, 1961-4, 1962-8, 1963-1*
DDR	1960-3, 1961-8, 1962-8, 1963-1*
Hungary	1960-3, 1961-4, 1962-6
Poland	1960-3, 1961-4, 1962-9+1*
Romania	1961-3, 1962-6

* training system

SA-75MK Dvina "three van" (SA-2B) with V-750VK 11DK (Guideline mod.1)

Systems exported outside of the Warsaw Pact were designated SA-75MK, the "K" standing for "Commercial," the standard Soviet designation for export grade weapons.

Yugoslavia	1962-1+1*, 1963-2, 1964-1, 1966-1
Indonesia	1962-7+2*
North Korea	1962-2, 1966-8, 1967-4, 1970-1, 1971-18, 1973-6
India	1963-1+1*, 1964-6, 1965-5, 1966-6, 1967-1, 1969-2
Cuba	1963-24+6*
Algeria	1965-1, 1967-2
Afghanistan	1965-1*, 1966-1, 1967-2
Vietnam	1965-16+1*, 1966-18+1*, 1967-42+2*, 1968-4, 1969-2, 1972-12
Egypt	1965-18+2*, 1966-9, 1967-2, 1969-8, 1970-10, 1971-3
Syria	1968-2, 1969-4+1*
Sudan	1969-1*, 1973-3
Somalia	1973-3, 1976-4
Yemen	1977-4

* training system

S-75 Desna (SA-2C) with V-750VN 13D (Guideline mod.2)

The definitive version of the "75" design, the 6cm wavelength ("N" band in Russia) **S-75 Desna (SA-2C)** was fielded in the Soviet Union from 1959, with the **V-750VN 13D (Guideline mod.2)** missile. The name of the vans changed: P – fire control radar, U – fire control cabin, A – instrument cabin, (R – power distributor, and diesel generators).

This system introduced the SDC (Moving Target Indicator), making it capable of tracking low flying targets against ground clutter.

Maximum target speed: 1900km/h (520m/s, Mach1.85)
Target altitude: 500m-24km
Maximum Range: 34km

On the 1st of May, 1960, a U-2 spy plane was successfully engaged by an S-75 Desna (SA-2C) SAM system over Sverdlovsk utilizing a V-750VN 13D (Guideline mod.2) missile.


Pieces of the U-2 spy plane in Moscow shot down by the S-75 Desna (SA-2C).

This version was only exported to Egypt, but in large numbers.

Egypt 1970-20, 1971-12

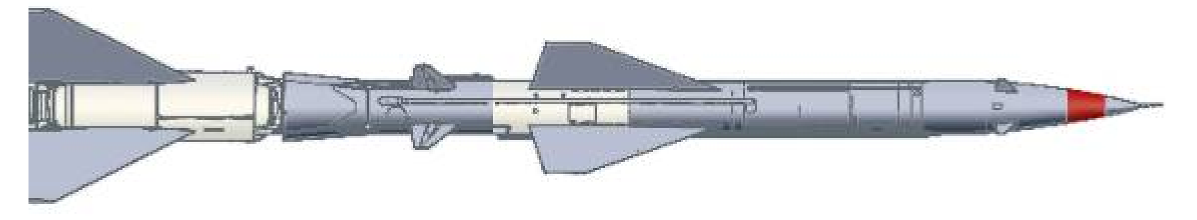
S-75V Volhov (SA-2E) with V-755 20D (Guideline mod.3)

In 1961, the last major version, of the "75" system was fielded with SDC (Moving Target Indicator), for tracking low flying targets against ground clutter, and LORO (Lobe On Receive Only), that tripled the density of the target tracking microwave energy in a given airspace. Again the name of the vans changed: PV – fire control radar; UV – fire control cabin; AV – instrument cabin; RV – power distribution cabin and diesel generators.



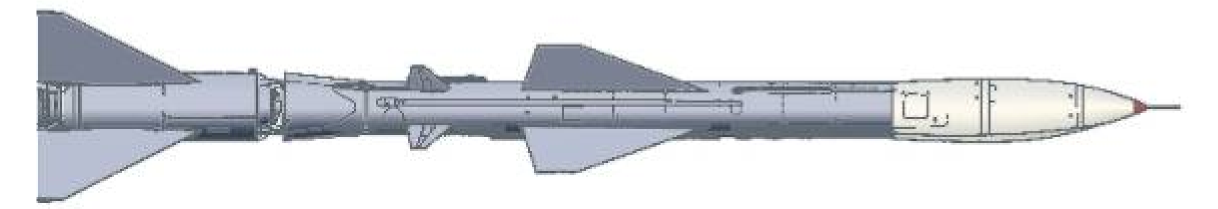
Maximum target speed:
2300km/h (640m/s, Mach2.3)
Target altitude: 3-30km
Maximum Range: 43km

The **V-755 20D (Guideline mod.3).**



S-75M1 Volhov (SA-2E) with V-755 20DP (Guideline mod.3) and V-760 15D (Guideline mod.4)

In 1964, the next Volhov version, introduced the nuclear tipped **V-760 15D (Guideline mod.4)** missile, with 15kt nuclear warhead, and the RD-75 Amazonka range-only radar.



With the improved **V-755 20DP (Guideline mod.3)** missile, maximum range was extended to 55km against subsonic targets.

SA-75M/MK Dvina "doghouse" (SA-2F) with V-750VM/VMK 11DM/DMK (Guideline mod.1)

During the Vietnam War, the Soviet Union rejected the transfer of the more advanced S-75M Volhov (SA-2E) system to the warzone, in the fear of getting it compromised. Instead from 1969, they exported an upgrade kit, containing several internal advances and the capability for manual optical target tracking from the "doghouse" cabin located on the top of the antenna. Eventually all exported basic **SA-75M Dvina (SA-2B)** systems received this upgrade, with the improved **V-750VM/VMK 11DM/DMK (Guideline mod.1)** missile.



With **11DM/DMK V-750VM/VMK** missile:

Maximum target speed was increased to: 3600km/h (1000m/s, Mach3.6)
Target minimum altitude was decreased to: 300m

Earlier **11D/DK V-750V/VK** missiles could also be used.

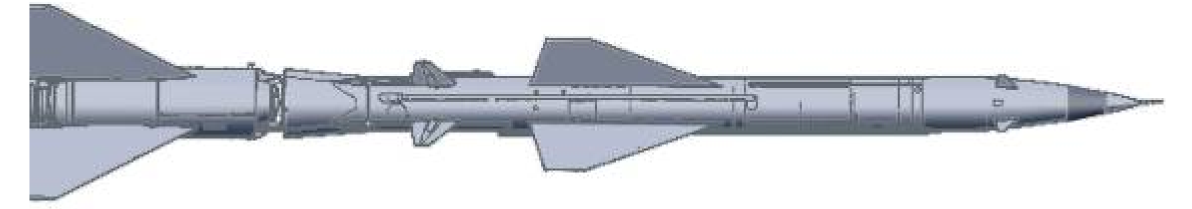




12/26/1972, B-52D "Ebony-02" disintegrates over Hanoi, killed by an SA-75MK.

S-75M2 Volhov (SA-2E) with V-759 5Ya23 (Guideline mod.5)

In 1971, the next Volhov version was introduced, the **V-759 5Ya23 (Guideline mod.5)** missile with improved maneuverability.



All earlier 20D/15D versions could also be used.

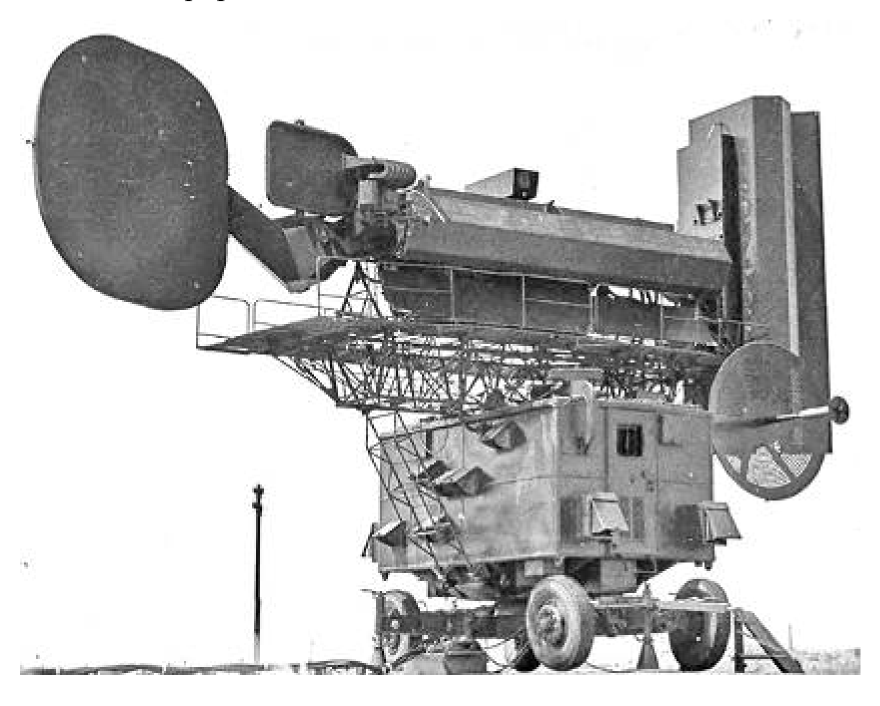
S-75M3 Volhov (SA-2E) with V-760V 5V29 (Guideline mod.4)

In 1975, the next Volhov version, introduced the GShV (Angle Deception Jamming Canceller) circuit, and the improved **V-760V 5V29 (Guideline mod.4)** nuclear tipped missile, that was based on the V-759 design.

All earlier 20D/15D/5Ya23 missile versions could also be used.

S-75M4 Volhov

During November of 1978, testing was finished of the next Volhov version.
It introduced the 9Sh33A “Karat” target tracking TV camera, a new narrow beam antenna system, capable of tracking low altitude small radar cross section targets, and the “Doubler” equipment to confuse Anti Radiation Missiles with a false emitter.



During 1978, the S-300PT Biryusa (SA-10A Grumble) system fielding started. All further development work on the S-75M4 was immediately stopped, but the advancements developed were made available as an upgrade package to earlier S-75 variants.

S-75M3-OP Volhov (SA-2E)

From 1983 an upgrade package made from the advances of the S-75M4 system become available. It introduced the 9Sh33A "Karat" target tracking TV camera.

The S-75M Volhov (SA-2E) system exports*

It is important to note, that during planned 5 year maintenance (overhaul), the older versions received the advances of the newer systems, so in theory all Volhovs were at the S-75M3-OP level after the middle of the 80's.

Czechoslovakia 1964-3, 1965-6, 1971-2, 1976-2, 1983-1, 1984-2, 1985-2
DDR 1964-4, 1965-4, 1970-4, 1971-1, 1972-4, 1974-2, 1975-2, 1976-6, 1977-2, 1983-1
Poland 1964-10, 1967-1, 1968-3, 1969-5, 1970-5, 1971-1, 1973-1, 1975-1
Romania 1964-4, 1965-2, 1968-1, 1975-1, 1976-1, 1977-1, 1978-1, 1982-2, 1983-3, 1984-3, 1985-4, 1986-4
Mongolia 1964-1, 1970-1

Yugoslavia 1966-2, 1967-2, 1970-1

Bulgaria 1969-2, 1970-1, 1974-1, 1981-1, 1983-1, 1985-4

Egypt 1973-8
Syria 1973-6, 1974-4, 1975-3, 1977-9, 1978-3, 1979-6, 1980-1, 1981-3, 1982-7, 1983-6, 1987-5
Iraq 1974-4, 1975-3, 1976-4, 1977-4, 1979-2, 1980-4, 1981-4, 1984-3, 1985-3, 1986-4
Libya 1975-12, 1977-2, 1978-8, 1979-4, 1982-6, 1984-3, 1985-4

Hungary 1977-1, 1978-4, 1982-2, 1983-3, 1984-3

Ethiopia 1978-4, 1985-3
Vietnam 1979-8, 1980-3, 1982-3, 1985-4, 1986-8, 1987-10
Yemen 1980-3, 1981-9, 1983-3, 1987-3
Cuba 1981-3, 1983-3, 1984-5, 1985-3, 1987-4

Angola 1984-3, 1987-4
Mozambique 1986-3
North Korea 1986-3

These numbers include training systems also.

During its service, the “75” SAM system was more effective than any contemporary Soviet fighter type. Among the SA-2’s achievements are shooting down Francis Gary Power’s U-2, killing fifteen B-52s during the Linebacker II raids on North Vietnam and downing scores of fighters over the Middle East, Southern and Southeast Asia.
The SA-2 was constantly improved during its lifetime (SA-2A ... F), and this was reflected in the types of targets used for practice shooting at Asuluk in the Soviet Union.
- From 1962 the target was an F-86 Sabre imitator.
- From 1968, high speed high altitude target was introduced (H>16km, V>Mach2).
- From 1972, low altitude target was introduced (H<100m).

Between 1978-84 all Hungarian SA-75M Dvina (SA-2F) units were replaced with the more modern S-75M Volhov (SA-2E).

This program simulates the SA-75M/MK Dvina (SA-2F Guideline).
Keyboard references for the program:



Requirement to run this program

Computer must be able to display resolution 1280x1024 or above.

Engagement zone

The SA-75M has one target and three missile channels, meaning that it can track one target, and guide three missiles onto it. The maximum flight parameters of the target are 1000m/s (Mach 3.5) in speed, 34km (18 nm) in range, and 27km (89,000ft) in height.

Budapest – Dunaújváros - Miskolc destruction zone at the middle of the 1960's:

Switching Simulator on-off

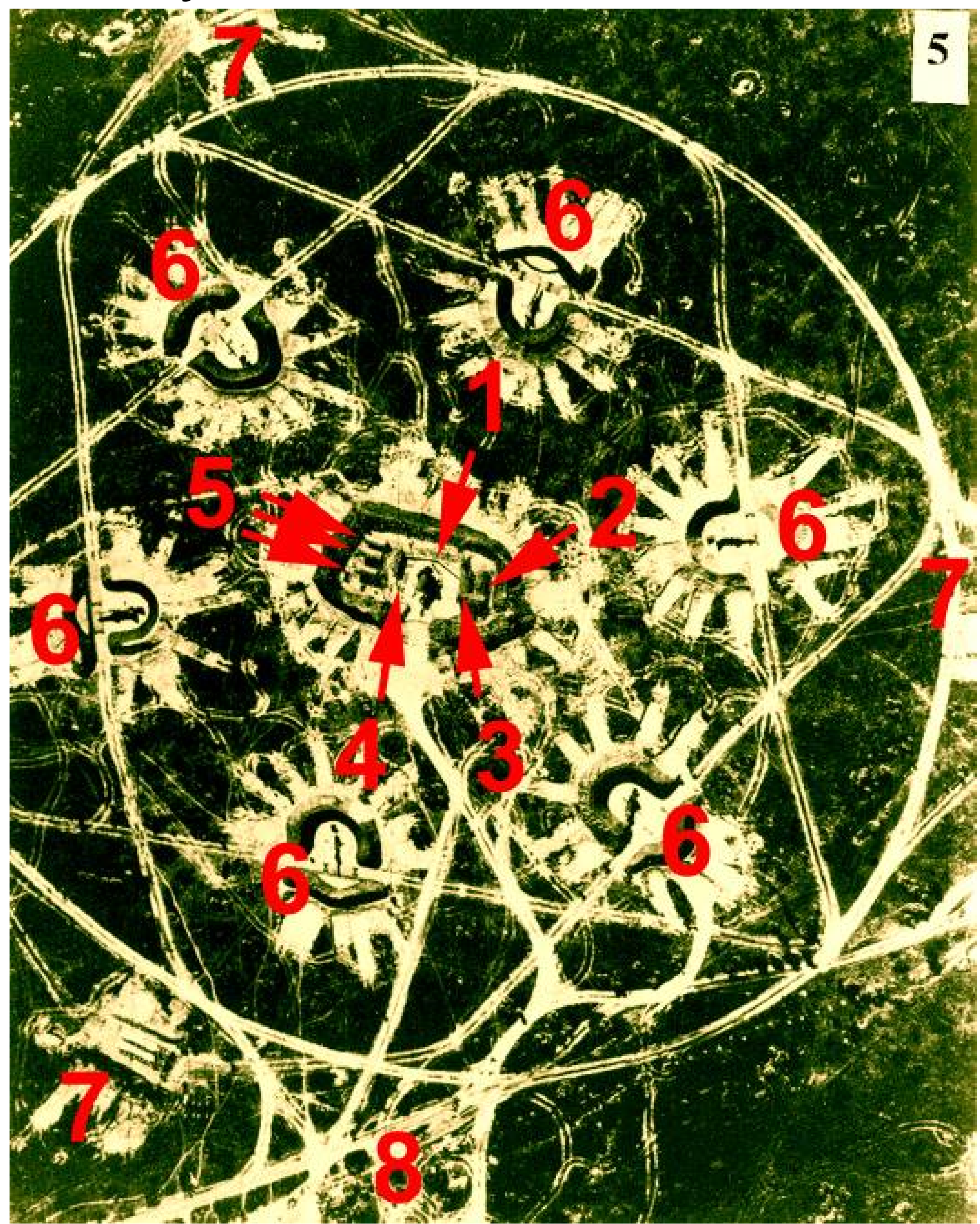
(Press the "Q" button on your keyboard to call up the I-66/I-64 panel)



If all four subsystems are ready for action (as indicated by green lamps - 1), then the system can be started by pressing switch (2). To turn off the simulation, push button (3).

AA – AA instrument cabin (analogue computer)
PMA - RMA power distribution cabin
ПАА – PAA, RSNA-75M (Fan Song F) fire control radar
УА – UA, fire control cabin (where we sit)

SAM Site layout



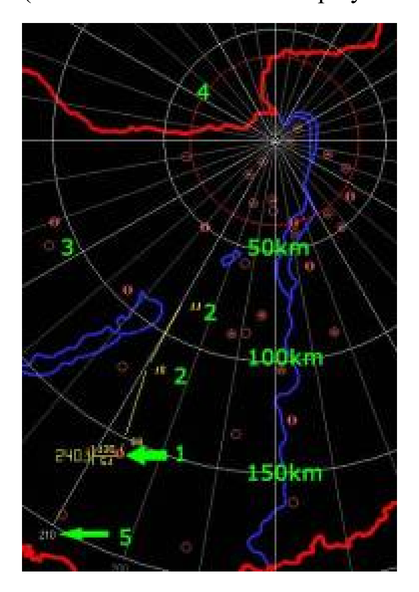
1. PAA cabin, RSNA-75M (Fan Song F) fire control radar.
2. UA fire control cabin (where we sit),
3. AA instrument cabin (analog computer),
4. RMA power distribution cabin
5. Three DES cabins (100kW diesel generators)
6. Six PU launchers
7. Six TZM PR-11 missile transporter - loaders
8. P-12 target acquisition radar

Methods of target acquisition

There are four possible methods of target acquisition:
- From the plotting table. This was used since the first fielding of the system and was developed by the British during the World War II.
- From the battery's early warning radars (P-12 Spoon Rest). These were introduced in 1962 and made the battery capable of autonomous target detection.
- From the integrated air defense system which was fielded in Hungary from 1980.
- From the RSNA-75M (Fan Song) radar using autonomous search

Plotting Board

(Push the "W" button to display the Plotting Board)



Target parameters, detected by radar battalions (red circles in the table - 3) are written on the glass plotting board.

Target parameters (1) :

2401 | 130 / 51

2401 (Tall numbers) – target number

24 – Tactical number of the radar battery, detected the target first

01 – Sequential number of the target, detected by the same radar battery

130 (numerator) – Target height in hectometers (130x100=13,000m or 43,000ft)

51 (denominator) – type of the target (friendly – *1pcs*)

(tens digit)

0 – jamming target
1 – friendly target
2 – identified target
3 – border violator
4 – supervisor target
5 – own target (friendly return)
6 – rule violator target
7 – practice target
8 – enemy
9 – target without IFF

(ones digit)

Number of the targets in the formation (1pcs)

The location of the target (2) is updated every minute, and a timestamp is noted (9, 10, 11, …). In the plotting table, the destruction zone of the battery is marked by a red circle (4). White circles are marking the range from the battery (50-100-150-200km). The target direction can be read from the radial lines, (thin line every 10°, bold line every 30°).

Target data read from the plotting board, above: At time 11, one own plane, direction 210°, range 80km, height 13km.

P-12 (Spoon Rest-A) target acquisition radar

(Push the “X” button to display the P-12’s scope)



Metric wavelength, P-12 target acquisition radar.

The VHF band target acquisition radar detection range is 160km for fighter sized targets (1).

P-12 radar, remote indicator

1
50km
100km
150km

1. *Target at 209°, 95km distance*

Clicking within the scope area, with left or right mouse button will change its displayed range between 90-180-360km.

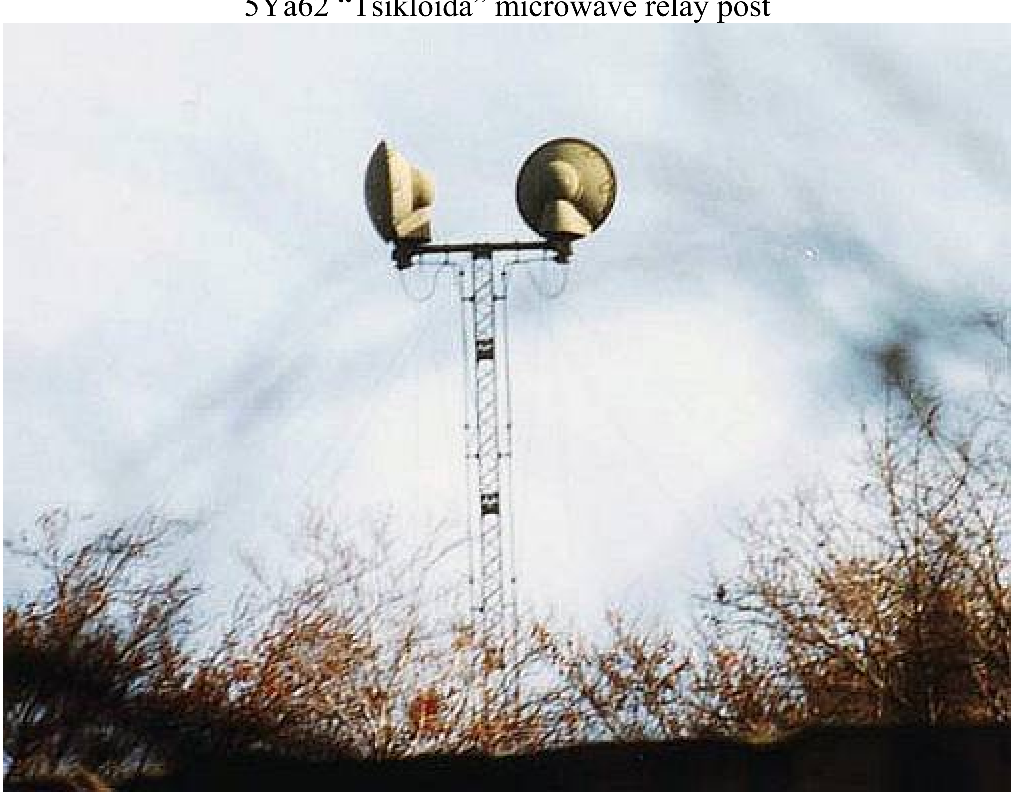
Vector-2VE/Senezh-ME, Integrated Air Defense System (IADS)

IADS function is to automate pairing of targets with engagement weapons (fighters or SAMs). It uses information from radar battalions and a data link to transmit the designated target's location to the SAM battalion every once every 10 seconds. The SAM battery has two connections to the IADS:

- The main connection is by ground cable
- The backup connection is by the 5Ya62, 5Ya63 "Tsikloida" (microwave relay)

The IADS interface to the SAM battery is the 5F24 cabin.

5Ya62 "Tsikloida" microwave relay post



Vector-2VE

Fielded in 1980, at the fortified base "20", near the city of Érd.
Capable of directing …

14 SAM batterys (SA-2 Guideline, SA-3 Goa)
6 fighter formations (MiG-21 Fishbed, MiG-23 Flogger)

… automatically, against 40 hostile targets simultaneously.

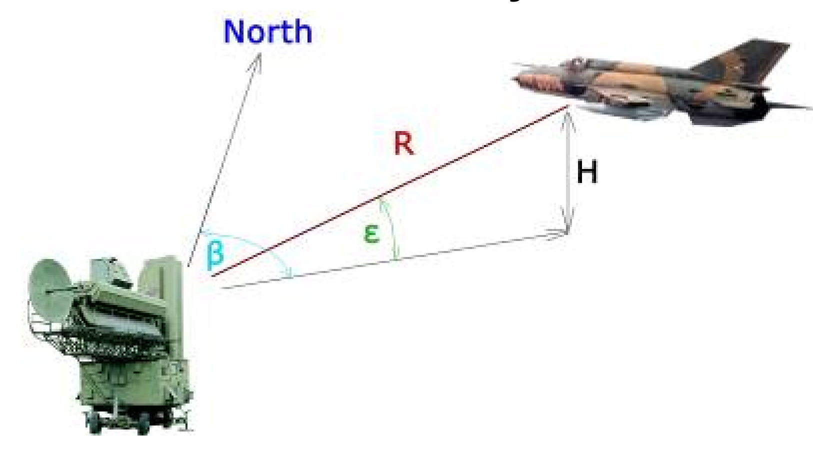
Senezh-ME

Fielded at Szarvaspuszta, during 1988, at the fortified base "50".
Capable of directing…

17 SAM batterys (SA-2 Guideline, SA-3 Goa, SA-5 Gammon, SA-10 Grumble), altogether 24 target channel
MiG-21, MiG-23, MiG-25 fighter formations

… automatically, against 50 hostile targets simultaneously.

Parametric coordinate system



R – target range
H – target height
ε (epsilon) – elevation (antenna up - down)
β (beta) – azimuth (antenna left - right)

RSNA-75M (Fan Song F) fire control radar

The basic version (SA-2B) was built since 1960, and its upgrade (SA-2F) become available during the Vietnam War. Hungary fielded from 1960.

RSNA-75M Fan Song F (PAA cabin) in detail



1. P-16: dm wavelength, missile command transmitter antenna.
2. PA-12: 10cm wavelength, wide beam, elevation (ε - epsilon) antenna.
3. PA-11: 10cm wavelength, wide beam, azimuth (β - beta) antenna.
4. Azimuth dummy load antenna. The elevation dummy load antenna is at the back of the cabin.
5. PAA-00 optical target tracking cabin (doghouse), used only with the Fan Song-F version.

Switching on the RSNA-75M Fan Song F

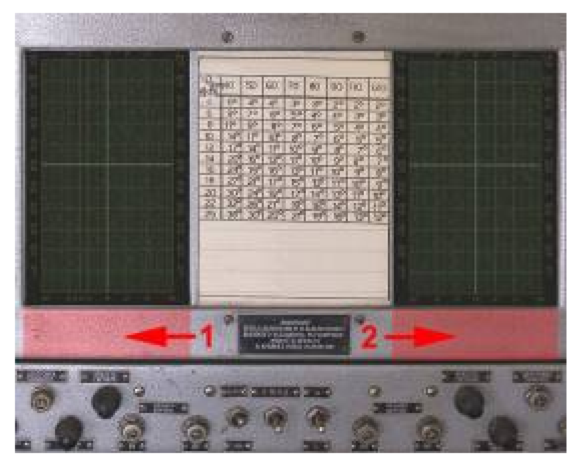
(Push the “Q” button) (Push the “Z” button)



1. Transmitter on
2. Switching between antenna and dummy load. (Antenna - up / dummy – down)
3. Transmitter off, receiving only. (used to track noise jamming targets)

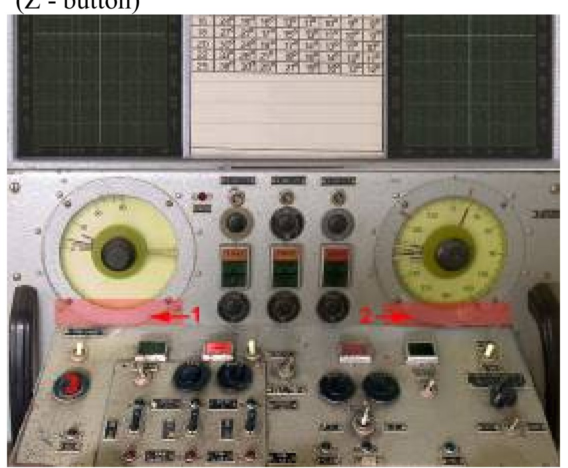
Rotating the RSNA-75M (Fan Song F)

(A - button)



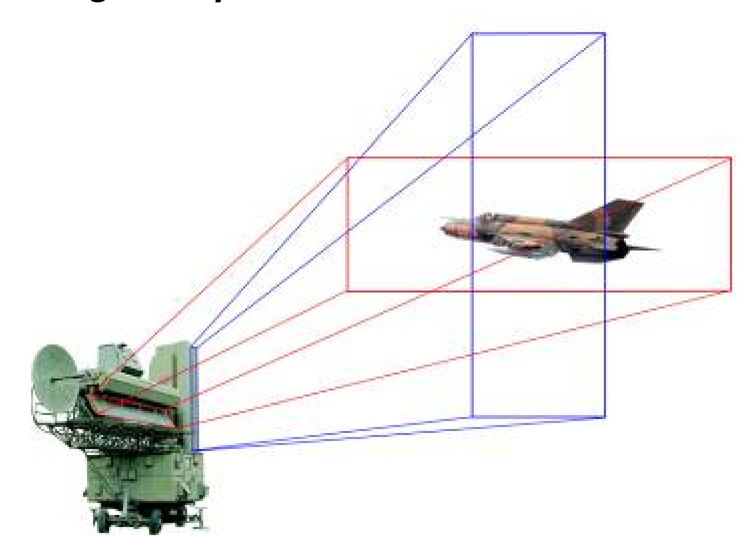
The left indicator is for the epsilon (elevation) plane, the right is for the beta (azimuth) plane.
Holding down the left mouse button in the red area (1), and moving it to right-left, we can rotate the PAA in the ε plane (up-down).
Holding down the left mouse button in the red area (2), and moving it to right-left, we can rotate the PAA in the β plane (right-left).


(Z - button)



The green round instruments below the indicators show the PAA's current orientation. Black pointers show the direction of the PAA, while red pointers show the direction of the missile launchers.
If we lower the antenna below zero ($\varepsilon<0^\circ$), it will jam down, and cannot be raised. In this case, we need to push the jam release button (3), before we can raise it again.

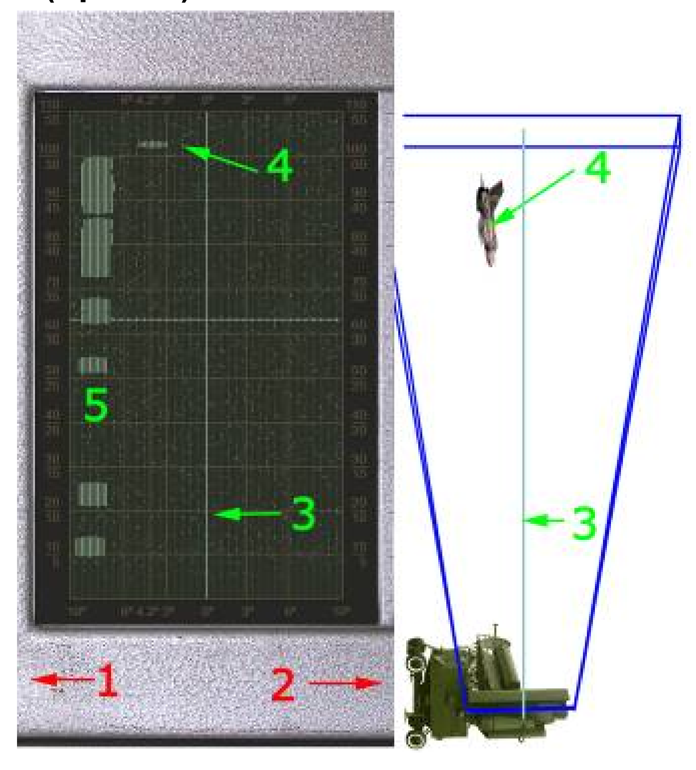
Target Acquisition



The 20º wide beam maximum detection range for a large target is 110km.
Detection range for a fighter-sized target is around 70km.
The 750kW radar impulses are emitted, and the returns from the target and missiles are received by:
(ε - epsilon) elevation: PA-12 antenna (**blue beam**)
(β - beta) azimuth: PA-11 antenna (**red beam**)

Understanding the indicators

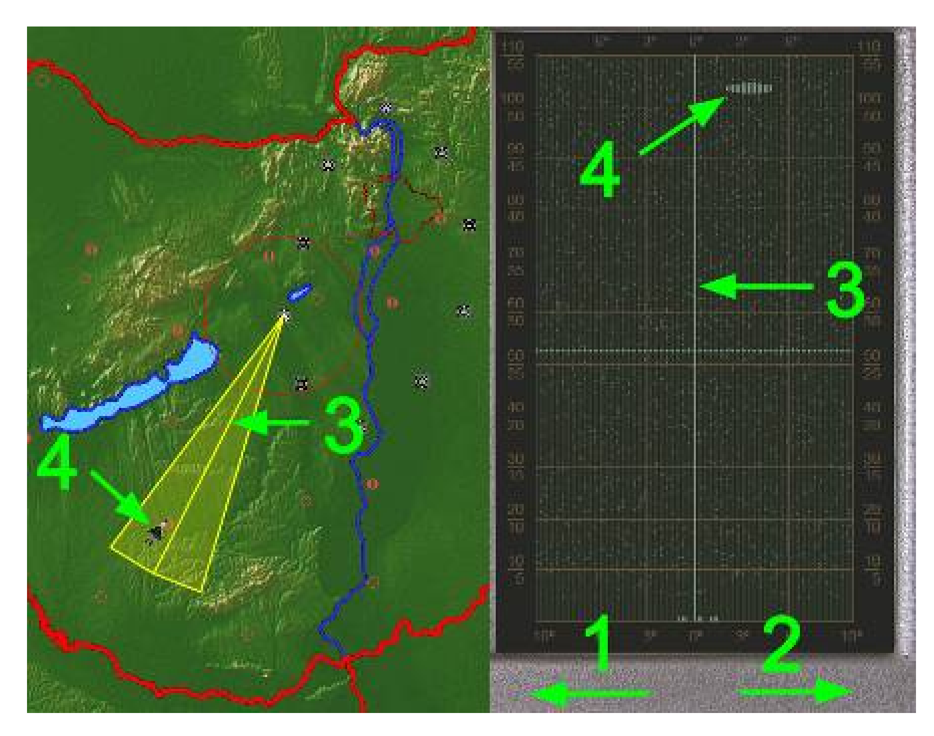
ε (Epsilon) – elevation – left side indicator – up/down direction



1. Direction down
2. Direction up
3. Boresight
4. Target under the boresight
5. Reflection from the ground

β (Beta) – azimuth – right side indicator – right/left direction

1. Direction left
2. Direction right
3. Boresight
4. Target at the right of the boresight

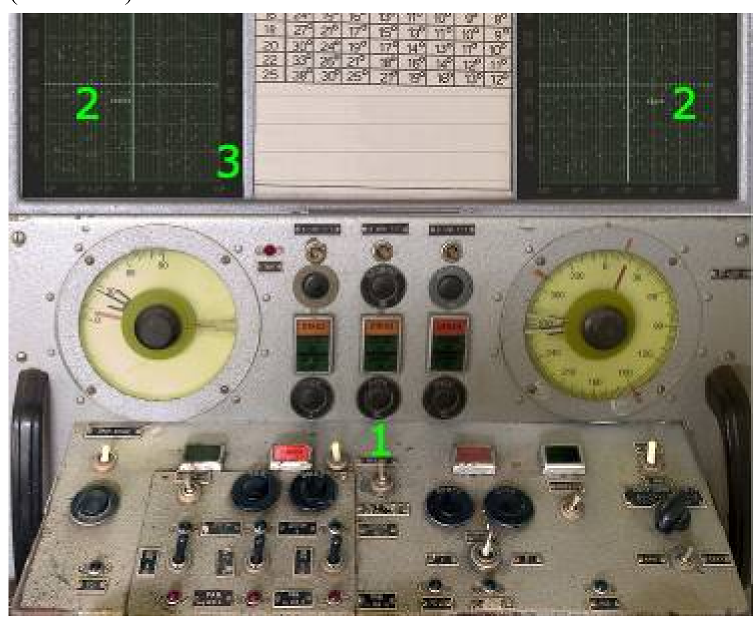


Range modes

Two main range modes can be selected, 55km and 110km. In 110km mode, only half of the electromagnetic impulses are sent, as they have to travel double range, compared to the 55km mode.

110km

(Z - button)

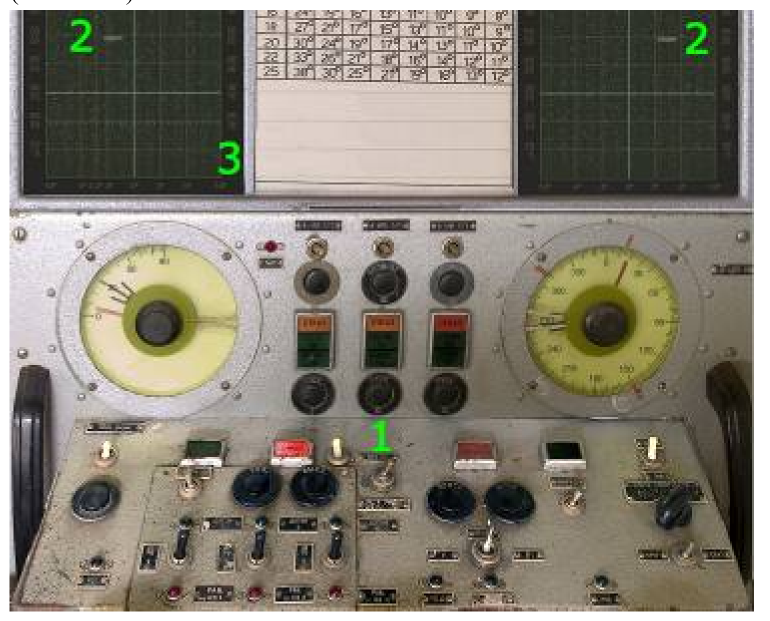


1. Range selector switch (**<u>left 110km</u>** – right 55km)
2. Target at 28km. The upper range scale should be used.
3. Range scale.

Both scales are always visible.
(5-55 and 10-110)

55km

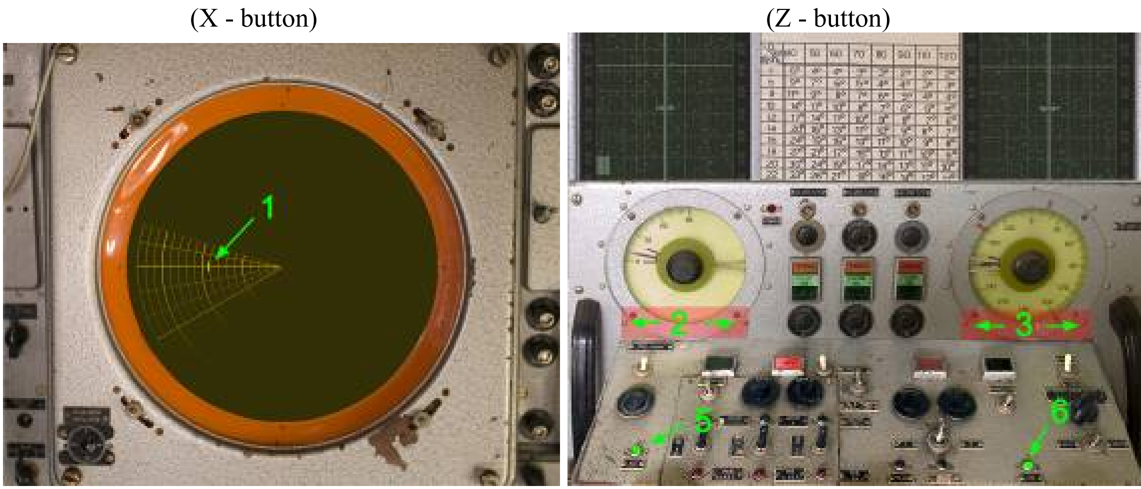
(Z - button)



1, Range selector switch (left 110km – **<u>right 55km</u>**)
2, Target at 24km. The lower range scale should be used.

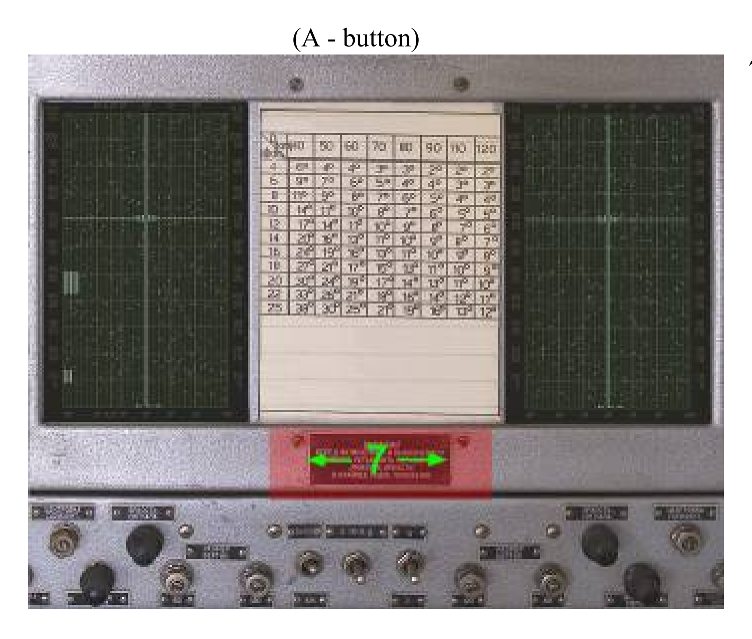
Target acquisition using P-12 Spoon Rest-A Radar

(X - button) (Z - button)



1. Target at 271˚, 93km range.
2. Holding down the left mouse button in the red area (2), and moving it to right-left, we set 4° in the ε plane on the green circular indicator above.
3. Holding down the left mouse button in the red area (3), and moving it to right-left, we rotate the PAA to 271˚ in azimuth. If the target cannot be seen, we slowly raise the SNR by holding down the left mouse button in the red area (2) and moving it right.
4. When the target shows up, we acquire it (see: rotating the RSNA-75M). If the bore sight touches the target, we can click with the right mouse button in the red area (2), and the target gets into automatic tracking in elevation. The PCε (Target is in automatic tracking – in elevation) lamp is illuminated (5).
6. We acquire the target in azimuth (see: rotating the RSNA-75M). If the bore sight touches the target, we can click with the right mouse button in the red area (3), and the target gets into automatic tracking in azimuth. The PCβ (Target is in automatic tracking – in azimuth) lamp is illuminated (6).

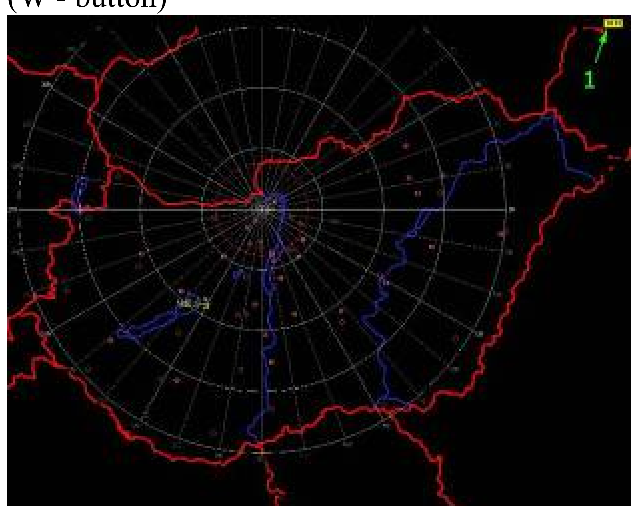
(A - button)



7. Holding down the left mouse button in the red area, and moving it to right-left, we can move the range bore sight (further-closer). If the bore sight touches the target, we can click with the right mouse button in the red area (7), and the target gets into automatic tracking in range.

Target acquisition with Vector-2VE/Senezh-ME, IADS

(W - button)



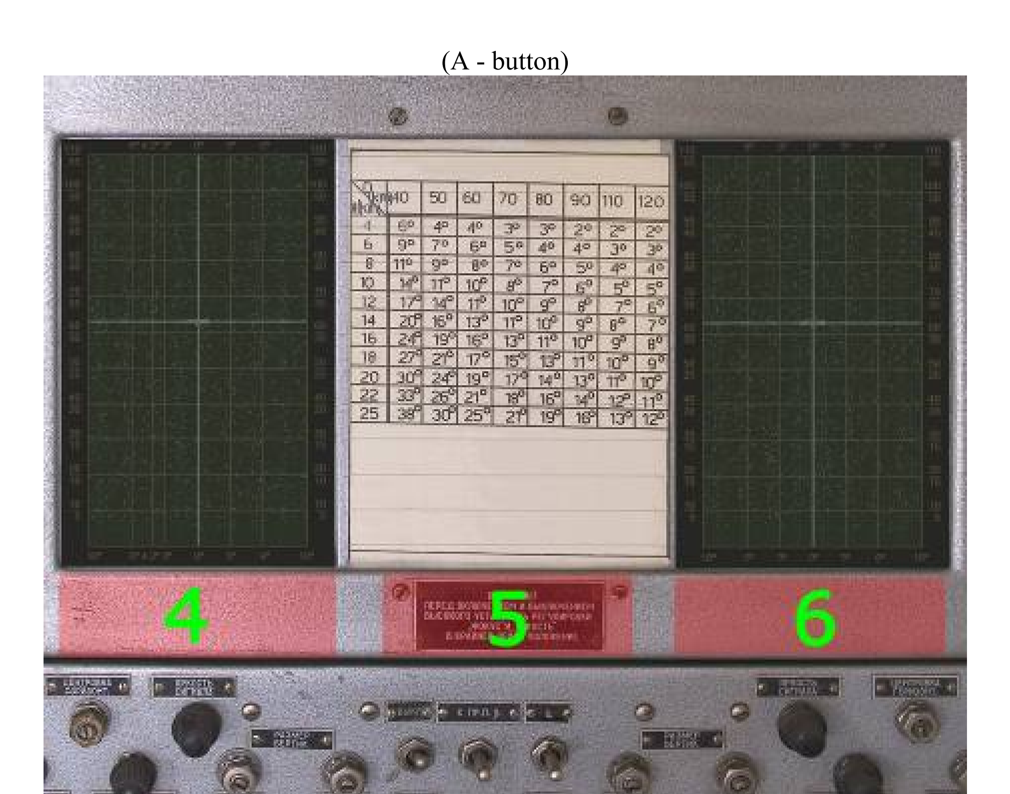
1. Clicking the target number in the plotting table, we can select automatic target acquisition.
The IADS provides accurate target location once every 10 seconds.

(Z - button)



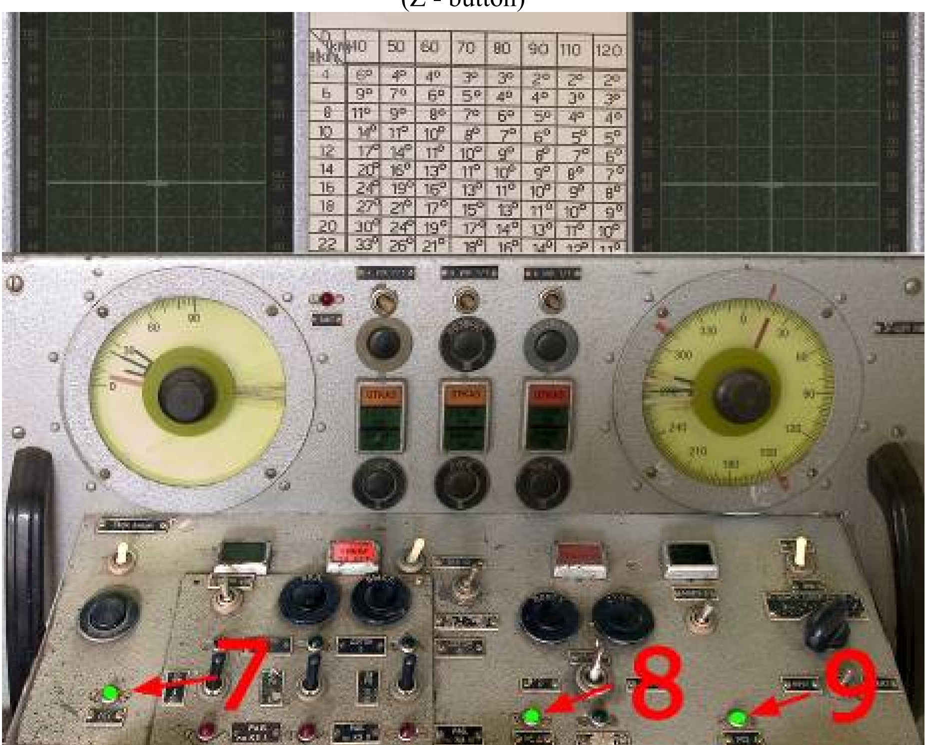
2. ВКЛ. ЦУ, (receiving target acquisition) switch - right.
In azimuth, elevation, and in range, the RSNA-75M is continuously following the IADS provided target acquisition, in every 10th second.
3. Target.

(A - button)



If the boresight touches the target, we can click with the right mouse button in the red area (4-5-6), and the target gets into automatic tracking in elevation – range – azimuth.

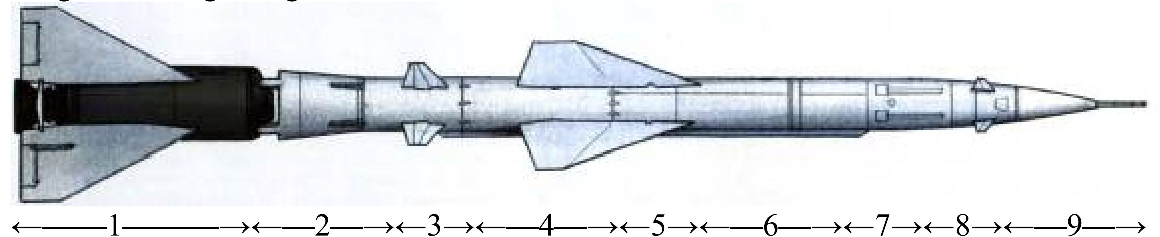
(Z - button)



7. The PCε (Target is in automatic tracking – in elevation) lamp is illuminated.
8 The PCД (Target is in automatic tracking – in range) lamp is illuminated.
9. The PCβ (Target is in automatic tracking – in azimuth) lamp is illuminated.

V-750 1D (Guideline Mod.0) surface to air missile

Fielded from 1957, the first type of missile fielded with the Dvina system. Launch weight: 2,300kg. Length: 10.7m.

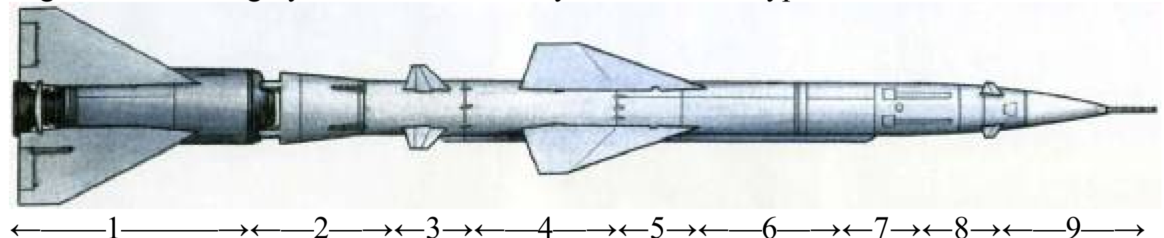


←——1———→←—2—→←3→←—4—→←5→←—6—→←7→←8→←—9—→

1. **I. I. Kartukov - PRD-10 solid fuel booster.**
   Propellant: 14pcs nitrocellulose tube (outer/inner Ø: 13,5/2,6cm, length: 1,8m)
   Weight of the igniter black gunpowder: 2kg
   Empty/launch weight – thrust: 300/900kg - 500kN
   Burn time: 3s
   Max speed: 550m/s (Mach 1.8)
2. **A. M. Isayev - S2.711 ZRD liquid fuel sustainer.**
   Weight / thrust: 47.7kg / 26,5kN
   Range: 29km
   Minimum/Maximum target altitude: 3/22km
   Max speed: 1000-1100m/s (Mach 2.9 to 3.2)
3. **OT-155 “Isopropyl nitrate” monocomponent fuel (“I” substance)**
   Weight / Composition: 20kg / 100% $C_3H_7NO_3$
   Colorless or yellow, extremely flammable, gas generator liquid, used to propel the turbo pump. Strong poison, causing hypotension (abnormally low blood pressure).
4. **AP-75 autopilot, steering fins.**
   Time to spin up gyroscopes before launch: 2 minutes
   Time to keep gyroscopes spinning without overheating: 25 minutes
5. **Air pressure bottle for the fuel and steering system. (270-350bar)**
6. **AK-20K “Melanj” oxidizer (“O” substance) tank.**
   Weight / Composition: 550kg / Nitric Tetroxide in solution with Nitric Acid, with Phosphoric and Fluoric acid inhibitors.
   20±2,5% N_2O_4, 73,4% HNO_3, 1-1,25% H_3PO_4, 0,5% HF, 2±0,8% H_2O
   Orange-brown, evaporating liquid. Self ignites combustibles. Highly corrosive, only few materials can withstand its effect: chromium steel, pure aluminum, glass, and for a short period, some rubber mixes.
7. **TG-02 “Samine” fuel (“G” substance) tank.**
   Weight / Composition: 250kg / mixture of xilidine, and triethylamine.
   50% $C_8H_{11}N$, 50% $C_6H_{15}N$
   Oily liquid, with color from yellow to dark-brown, and an odor typical for satured animes. Strong nerve agent, fatal concentration in air is: 18mg/liter!
8. **V-88 warhead.**
   Weight: 196kg
   Fragments: 8,200pcs
9. **Shmel radio proximity fuse, pitot tube**

V-750V/VK 11D/DK (Guideline Mod.1) missile

Fielded from 1958, the second missile type of the Dvina system, with increased sustainer engine thrust. Hungary fielded the Dvina system with this type of missile in 1959.



←——1———→←—2—→←3→←—4—→←5→←—6—→←7→←8→←—9—→

1. **I. I. Kartukov - PRD-18 solid fuel booster.**
   Propellant: 14pcs nitrocellulose tube (outer/inner Ø: 13,5/2,6cm, length: 1,8m)
   Weight of the igniter black gunpowder: 2kg
   Empty/launch weight – thrust: 300/900kg - 500kN
   Burn time: 3s
   Max speed: 550m/s (Mach 1.8)
2. **A. M. Isayev - S2.711V ZRD liquid fuel sustainer.**
   Weight / thrust: 47.7kg / 31kN
   Range: 34km
   Minimum/Maximum target altitude: 3/27km
   Max speed: 1000-1100m/s (Mach 2.9 to 3.2)
3. **OT-155 "Isopropyl nitrate" monocomponent fuel ("I" substance)**
   Weight / Composition: 20kg / 100% $C_3H_7NO_3$
   Colorless or yellow, extremely flammable, gas generator liquid, used to propel the turbo pump. Strong poison, causing hypotension (abnormally low blood pressure).
4. **AP-75 autopilot, steering fins.**
   Time to spin up gyroscopes before launch: 2 minutes
   Time to keep gyroscopes spinning without overheating: 25 minutes
5. **Air pressure bottle for the fuel and steering system. (270-350bar)**
6. **AK-20K "Melanj" oxidizer ("O" substance) tank.**
   Weight / Composition: 550kg / Nitric Tetroxide in solution with Nitric Acid, with Phosphoric and Fluoric acid inhibitors.
   20±2,5% N_2O_4, 73,4% HNO_3, 1-1,25% H_3PO_4, 0,5% HF, 2±0,8% H_2O
   Orange-brown, evaporating liquid. Self ignites combustibles. Highly corrosive, only few materials can withstand its effect: chromium steel, pure aluminum, glass, and for a short period, some rubber mixes.
7. **TG-02 "Samine" fuel ("G" substance) tank.**
   Weight / Composition: 250kg / mixture of xilidine, and triethylamine.
   50% $C_8H_{11}N$, 50% $C_6H_{15}N$
   Oily liquid, with color from yellow to dark-brown, and an odor typical for satured animes. Strong nerve agent, fatal concentration in air is: 18mg/liter!
8. **V-88 warhead.**
   Weight: 196kg
   Fragments: 8,200pcs
9. **Shmel radio proximity fuse, pitot tube**

V-750VM/VMK 11DM/DMK

Hungary fielded the improved maneuverability missile from 1974.
Minimum effective range was reduced to 5km
Minimum effective altitude was reduced to 300m.
Maximum target speed was increased to: 3600km/h (1000m/s, Mach3.6)

V-750VU/VKU 11DU/DKU

The upgrade of the original V-750V/VK 11D missiles started from 1975 in Hungary. The gyroscope spin up time was reduced from 2 minutes, to 30 second. Because of this modification, the time to keep gyroscopes spinning without overheating was decreased to 5 minutes from the original 25 minutes.

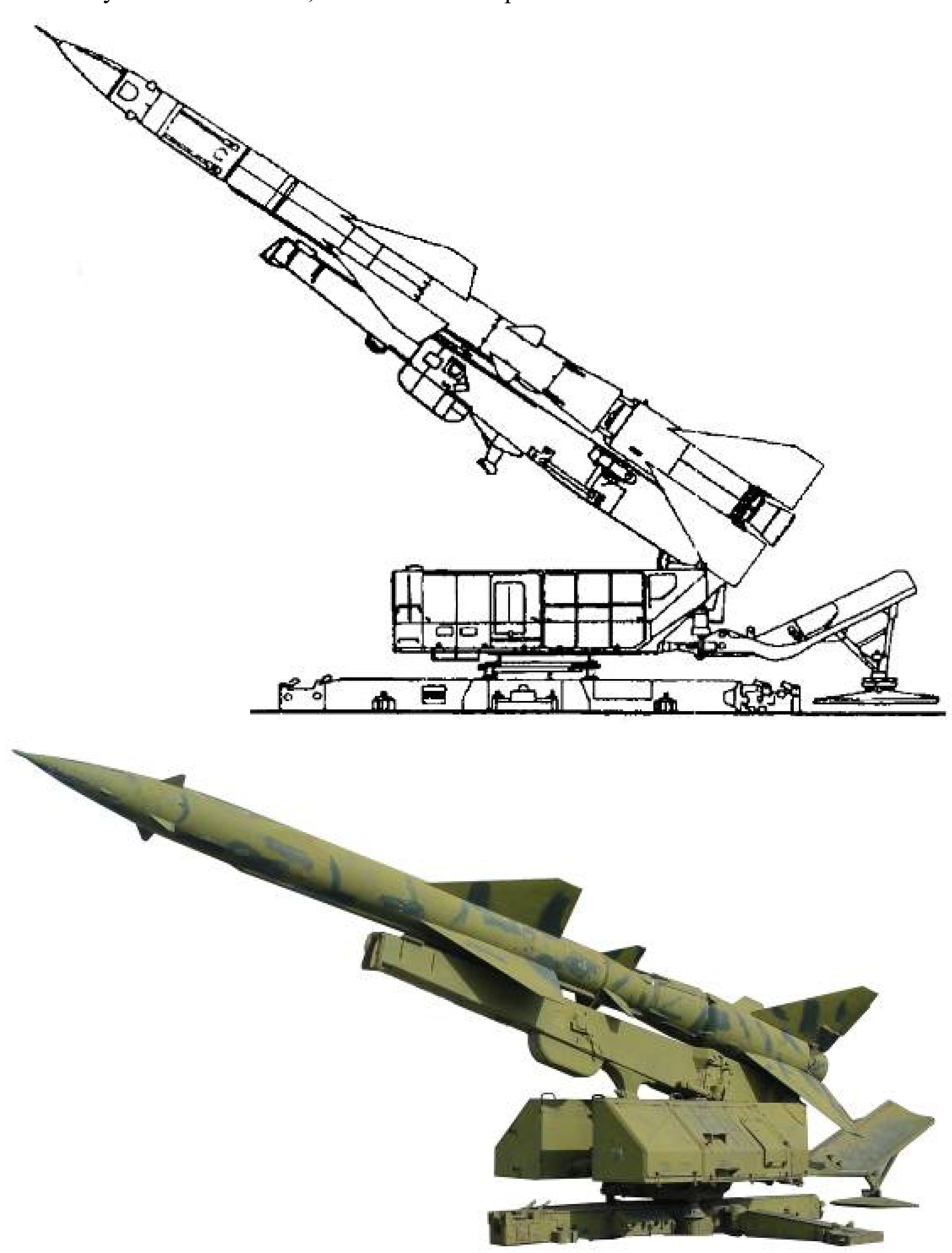
V-750VMU/VMVK 11DMU/DMVK

During the overhaul of V-750VM/VMK 11DM missiles, the gyroscope spin up time was reduced from 2 minutes, to 30 second. Because of this modification, the time to keep gyroscopes spinning without overheating was decreased to 5 minutes from the original 25 minutes.



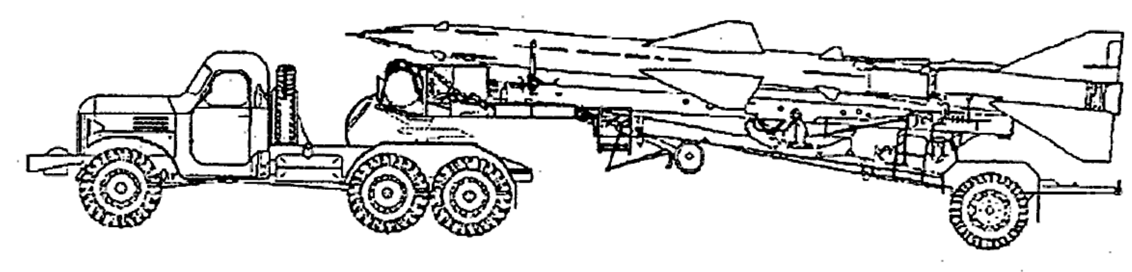
SM-63 PU launcher

The battery has six launchers, with one missile per launcher.



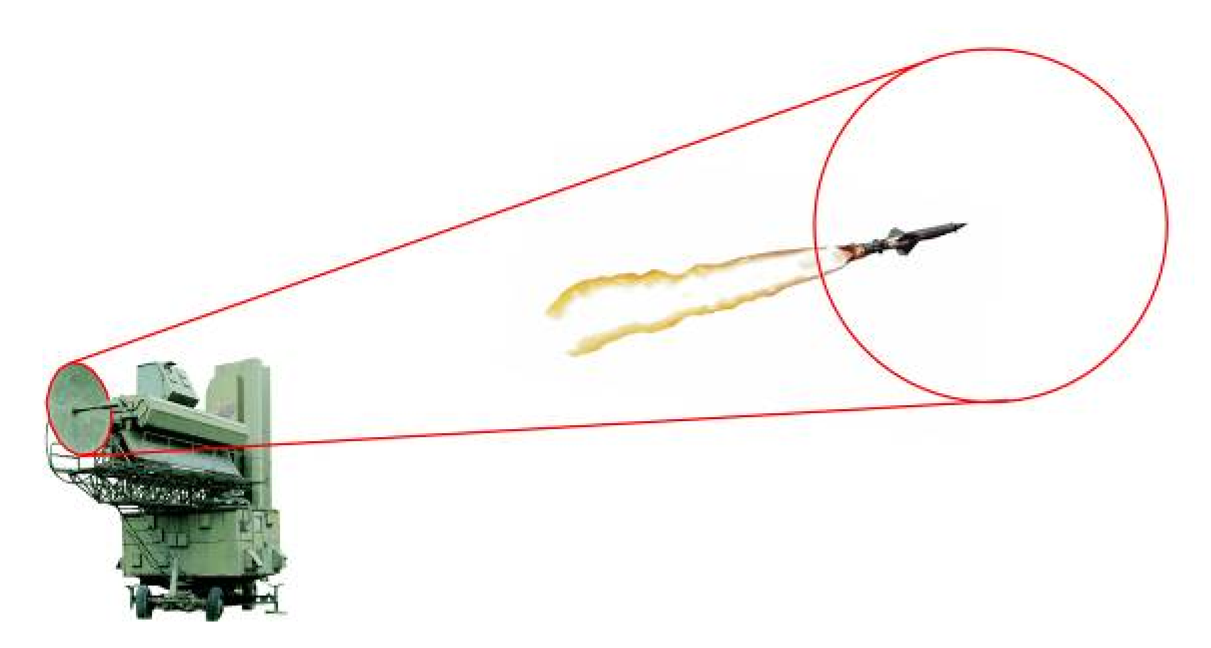
PR-11B TZM missile transporter-loader

The TZM is a PR-11B missile transporter-loader semi-trailer, towed by a ZIL-157 truck. Missiles are reloaded from the TZM to the SM-63 launcher. Each battery has 6 TZM vehicles, each carrying one missile.



Selection of the missile guidance method

The missile doesn't "see" the target, it flies by remote control. The P-16 decimeter wavelength antenna is transmits the guidance signal commands (K1, K2, and K3).
K1, K2 guidance signal (missile rudder angle command)
K3 radio proximity fuse arming command



(Q - button)



The missile guidance method is selected depending on the target altitude, and the existence of jamming.

After acquiring the target, its parameters can be read from:

- $\mathbf{P}_{\text{КМ}}$ – The Course Parameter shows how far to either side of the site the target will pass. If the target flies directly towards us, then P=0km.
- $\mathbf{H}_{\text{Ц КМ}}$ – Target altitude in km.
- $\mathbf{V}_{\text{Ц М/СЕК}}$ – Target speed in m/s.

Preparation for Missile launch

(Q - button)



1. **ТРЕВОГА**: The alarm can be sounded with this switch :)
2. **ГОТОВИТЬ**: The number of missiles to be prepared for launch should be selected. **0-3-6-Н**
   (Н - Prepare all available missiles)
3. **ПОДГОТ. ПУ 1...6**: The lights indicate that the missile is under preparation at the launcher (1..6).

The V-750 missile's gyroscope requires ~30 seconds spinning up time.

(Z - button)



When the missiles are ready, the **ГОТОВН. ПУ** lamps illuminate for the appropriate missile channels. The missiles could be kept in this ready to launch state for 5 minutes before the gyros overheated.

(Q – button)



4. Pushing this button, the system switches to "live fire" mode, and the **БР** lamp illuminates.

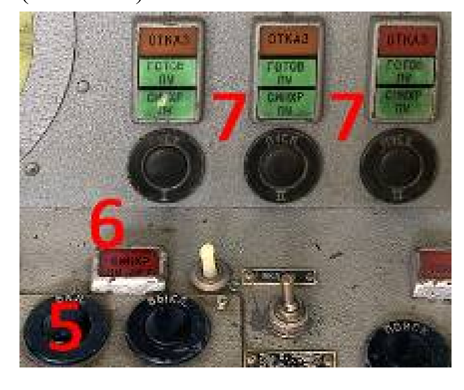


БР I...III: All missile channels should be switched to "live fire" mode.

During peacetime, these switches are sealed; no missile could be launched accidentally.

First you need to click on the seal, to remove it.

(Z - button)



5. **ВКЛ. СИНХР**.: Pushing this button, the launchers are synchronized with the alignment of the RSNA-75M fire control radar.
6. **СИНХР ПУ НЕТ**: Warning light extinguishes, synchronization is ongoing.
7. If the launcher is synchronized, the **СИНХР. ПУ** indicator is illuminated.

Selecting missile guidance method

Preparations for Shooting at High-Medium Altitude Targets

(Q - button)

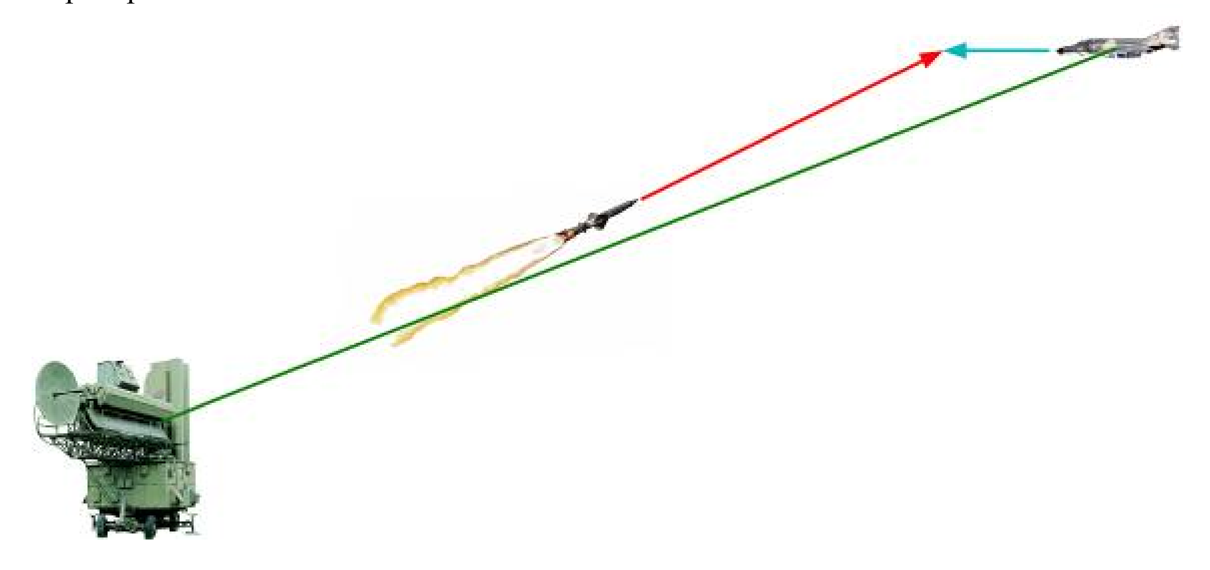


If the target altitude is above 5km, and its parameters are in the green zone (Hc 5-27km, Vc < 1000m/s), we set the missile radio proximity fuse to **РАБ. ОТ РВ** (use radio proximity fuse).

(Z - button)



The missile guidance channels are switched to **УПР** "half-lead" guidance method (middle setting). Using this guidance method, the missile is flying to pre-calculated impact point.



Preparations for Shooting at Low Altitude Targets

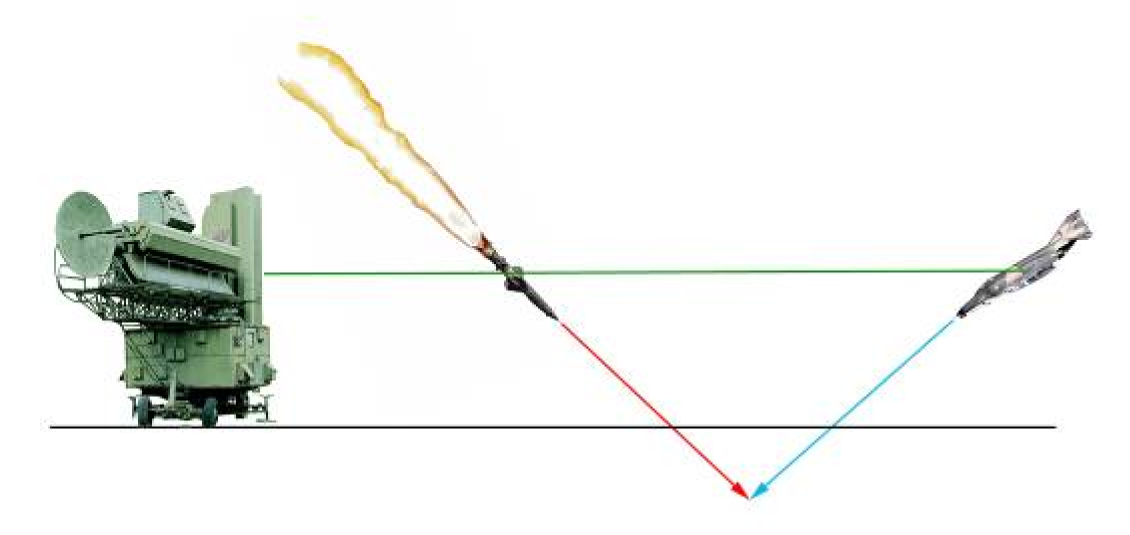
(Q - button)

(Z - button)



If the target parameters are in the green zone (H<5km, V<1000m/s), we use the (**K**) “half-lead, elevated by constant” guidance method (left setting).

During the Vietnam War, the American pilots discovered that a robust diving maneuver could cause the half-leading missile to crash into ground, as the calculated leading point is below the target. Using the “**K**” method the missile never aims below the target.



Depending on target altitude, there are two selectable radio proximity fusing methods...

Target altitude is above 300m

(Q - button) (Z - button)



1. We set the radio proximity fuse to standard arming method (rightmost setting), with 300m sensitivity.
2. **РАБ. ОТ РВ** (use radio proxy fuse) indication illuminates.
3. Channel selector switches are set at the middle state **PB I…III** (radio proxy fuse), no lamps are illuminated.

Target altitude is at or below 300m

(A - button) (Z - button)



4. If the reflected ground clutter is touching, or at the right side of the 4.2° elevation mark, the target is flying too close to the ground, and the radio proximity fuse cannot be used, as the echoes from the ground would confuse it.
5. We switch off the radio proximity fuse (lower setting) on the three missile channel. (**РАБ. по К3 I…III**) red indicator lamps illuminates. During this mode, the explosion of the missile is commanded by the RSNA-75M fire control radar, by transmitting the K3 command.

Preparations for Shooting at Receding Targets

(Z - button)

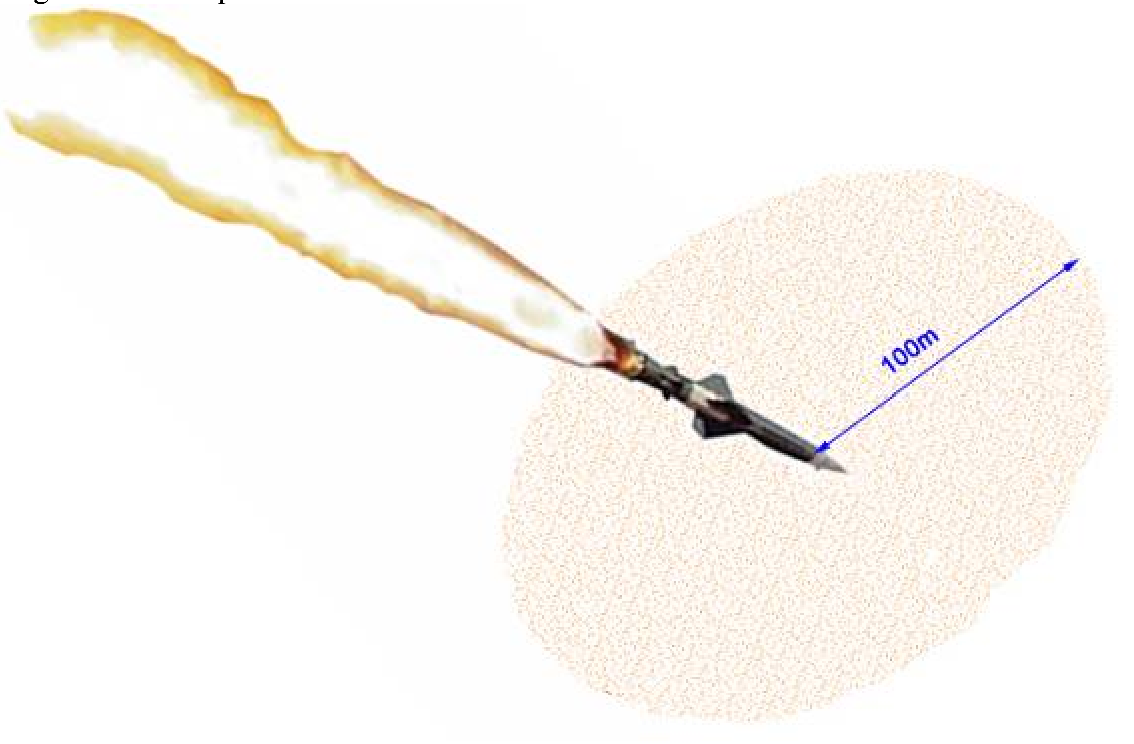


Against receding targets, the radio proximity fuse cannot be used, as it would detonate the missile prematurely.

6. We switch off the radio proximity fuse (upper setting) on the three missile channel, (**ДОГОН I…III**) green indicator lamps illuminates. During this mode, the explosion of the missile is commanded by the RSNA-75M fire control radar, by transmitting the K3 command.

Preparations for Shooting at Ground Targets

The SA-75M Dvina (SA-2F) system is capable of shooting on ground targets, closer than 18km (13.5 nm). The V-750V 11D (Guideline Mod.1) missile's fragments cover an area 200 m (660 feet) wide. The destruction power of the supersonic (~11gram weight) fragments is comparable to an M-14 rifle bullet.



(Q - button)



1. Rotate the selector to its leftmost setting, and the **ЗЕМЛЯ** (ground) lamp will illuminate.

(Z - button)

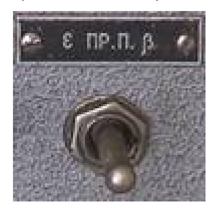


Select K, for the "half-lead, elevated by constant" guidance method.

Determining the missile's launch envelope

The launch envelope is depending on the target parameters (speed, altitude, course parameter), and the missile interception method (half-lead, three-point).
Using these data, the APP-75M instrument is continuously calculating, and displaying the launch zone range marks.

(A - button)



ε пр.п.β APP-75M instrument switch.
- Left: displaying the APP-75M range marks on the Epsilon indicator
- Middle: APP-75M instrument is switched off
- Right: displaying the APP-75M range marks on the Beta indicator

(Q - button)



УПР. Т/Т Missile guidance method input switch for the APP.
- Left: APP is calculating by "Half-lead" (**УПР**), or "half-lead, elevated by constant" (**K**) guidance method.
- Right: APP is calculating by "Three-point" (**T/T**) guidance method.

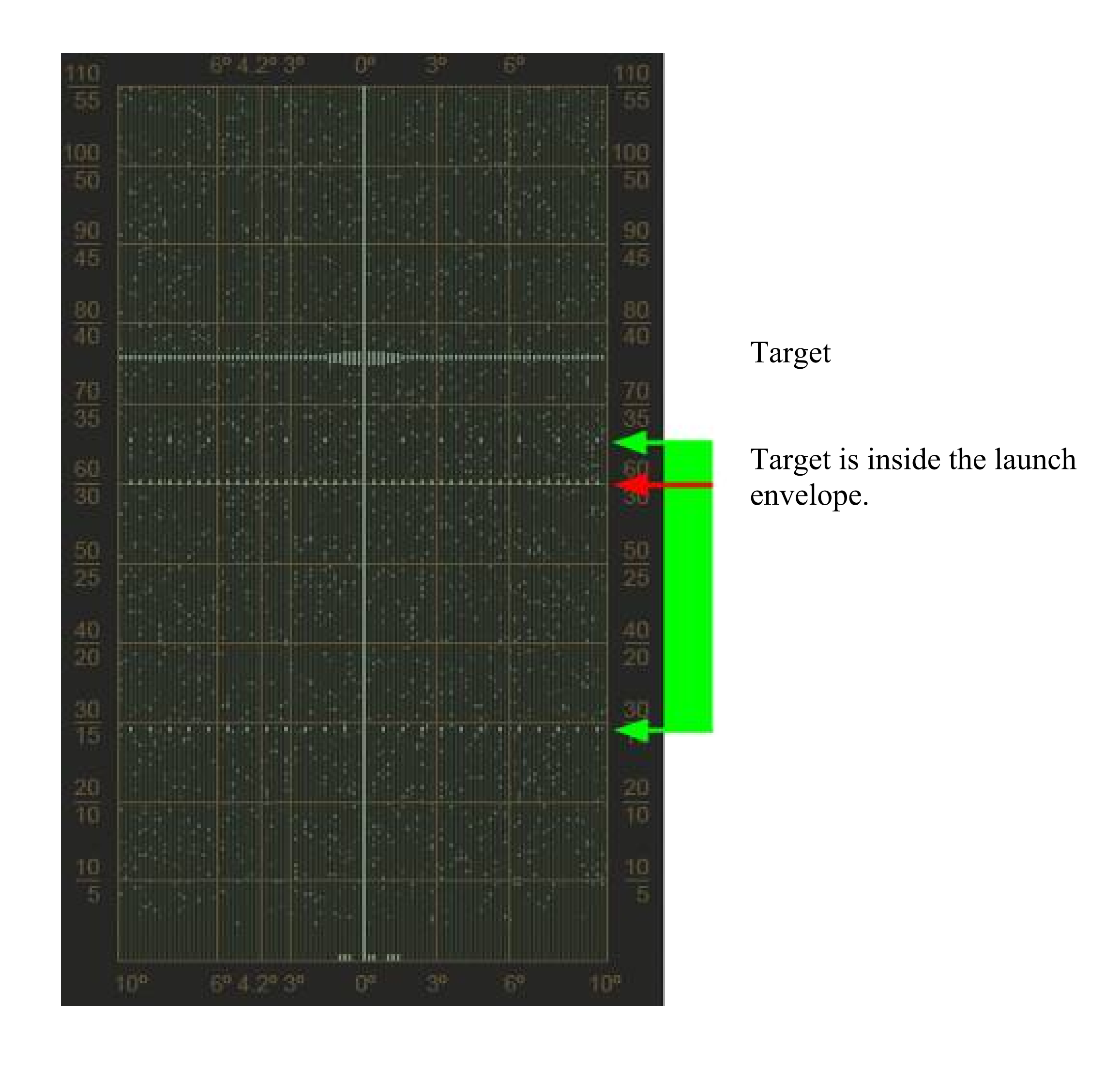
(A - button)

Target

Missile-Target theoretical impact point.

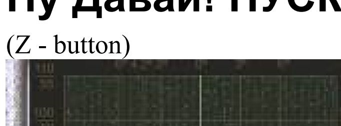
Missile's maximum range. If this mark is flashing, than the target is above the engagement envelope.

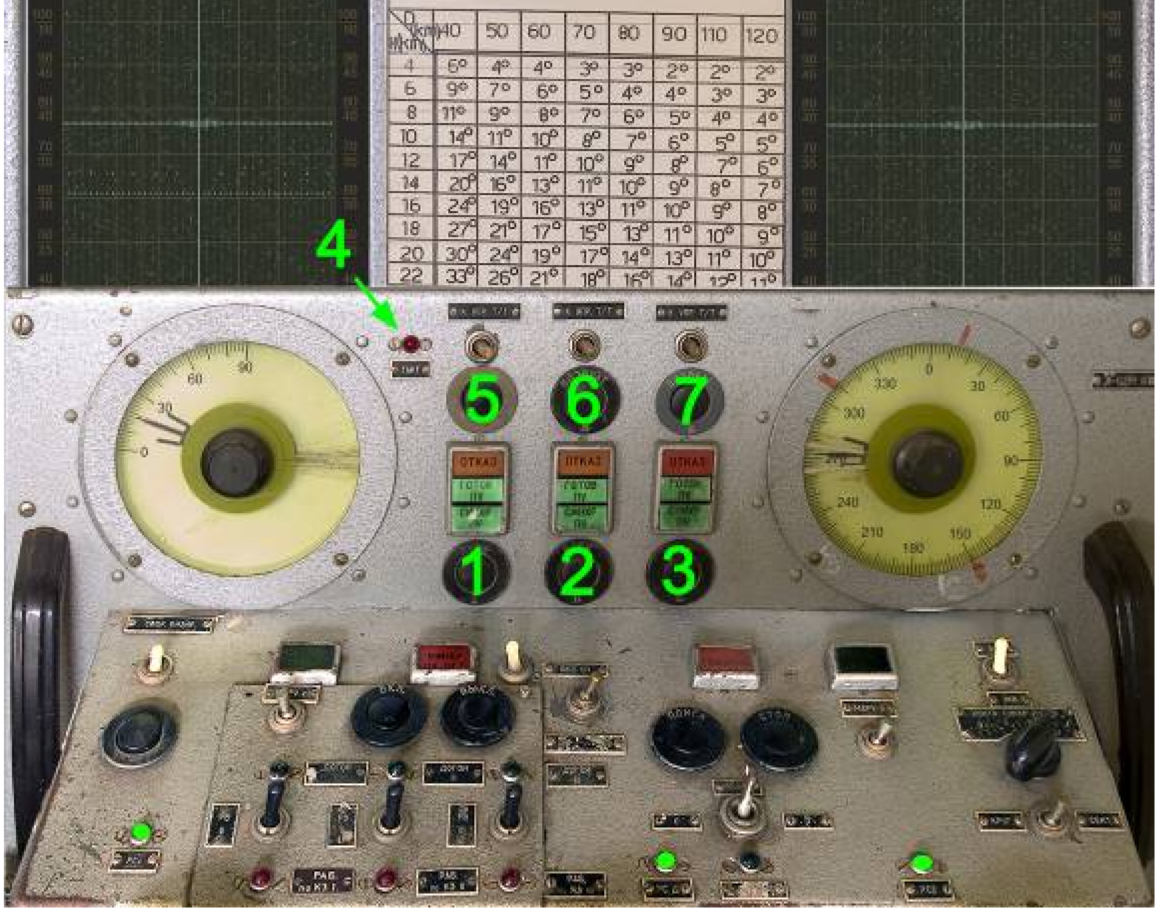
Missile's minimum range.
If this mark is flashing, than the target is under the engagement envelope.


6° 4.2° 3° 0° 3° 6°
110 55
100 50
90 45
80 40
70 35
60 30
50 25
40 20
30 15
20 10
10 5
10° 6° 4.2° 3° 0° 3° 6° 10°
Target
Target is inside the launch envelope.

Ну Давай! ПУСК!

(Z - button)





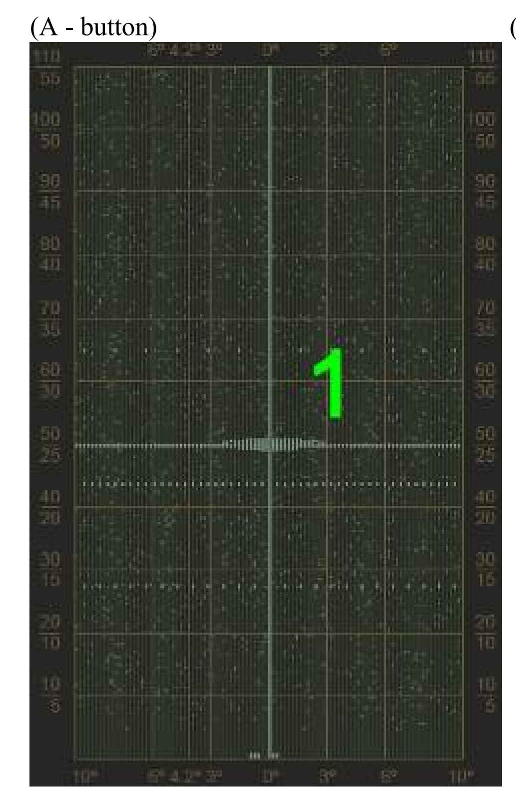
1-2-3. If the target is inside the launch envelope, the missile(s) can be launched with the **ПУСК I-II-III** button(s), keeping 6sec interval between the launches.
4. Keeping the 6sec separation between missile launches, the **ТАКТ** lamp is illuminated, blocking any premature launch.
5-6-7. Self destruction command to the missile(s) could be sent by the **ВОЗВРАТ I-II-III** button(s).

After pushing the **ПУСК** button, the launch command goes through the relays of the cabin, through the launcher, over the still attached OS-10 umbilical into the missile. First, the pyrotechnical switch opens the pressurized air valve. Pressurized air is required for the launch sequence, and during the flight, for operating the steering fins. It pushes up the electrolyte from the plastic bags into the battery cell. After a fraction of a second, the battery is capable of providing full power. When the onboard power supply was ready, the solid fuel booster is ignited.
This sequence is completed within ~2sec from pushing the **ПУСК** button.

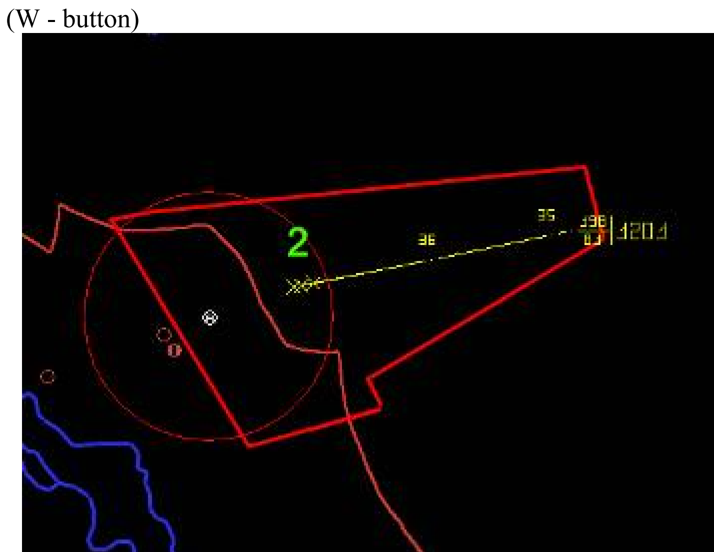
Observing the result of the shooting

Several factors are needed to be observed, to assess the result of shooting:

(A - button)

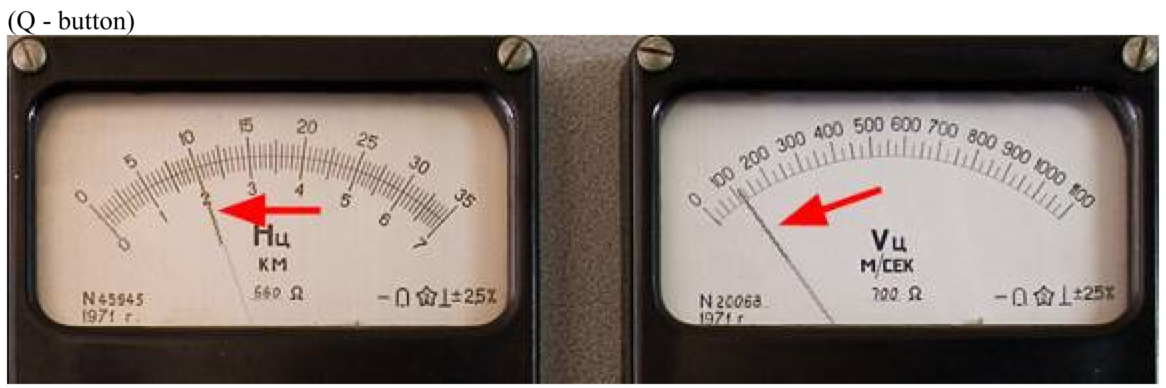


(W - button)



1. Target return “blossoms” when missile explodes.
2. The place of explosion is marked at the plotting chart by “X”. After successfully shooting at single target, the flight path of the target ends.

(Q - button)



Target destruction also shown by rapid decrease in target height and speed.

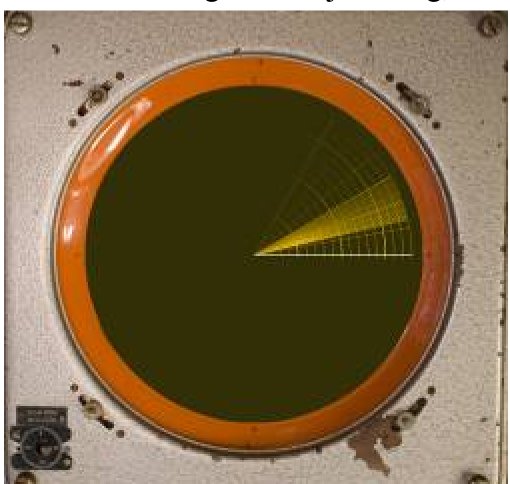
Electronic warfare

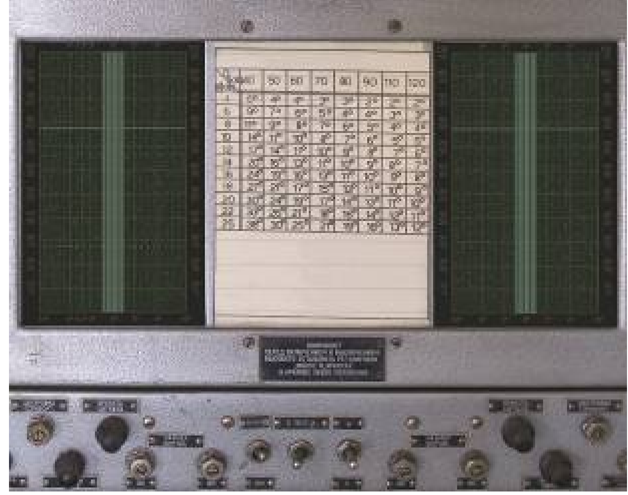
Noise jamming



Noise jamming pods, used since the middle of 60’s, are suppressing the radar echo of the carrier aircraft with strong noise, denying the range information from the fire control radar.

Metric wavelength noise jamming, centimeter wavelength noise jamming

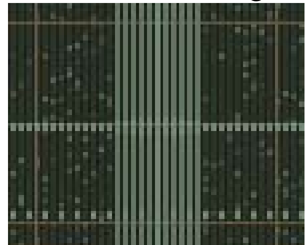




The noise jamming target is creating a vertical band in the indicators. It could be acquired in elevation and azimuth, but not in range.

Target is inside of the radar burn through range

If the target is inside the burn through range, the 750kW microwave impulses emitted by the RSNA-75M, and reflected from the target would be stronger than the noise jamming. In this case, the target could be seen through the jamming and could be range tracked.



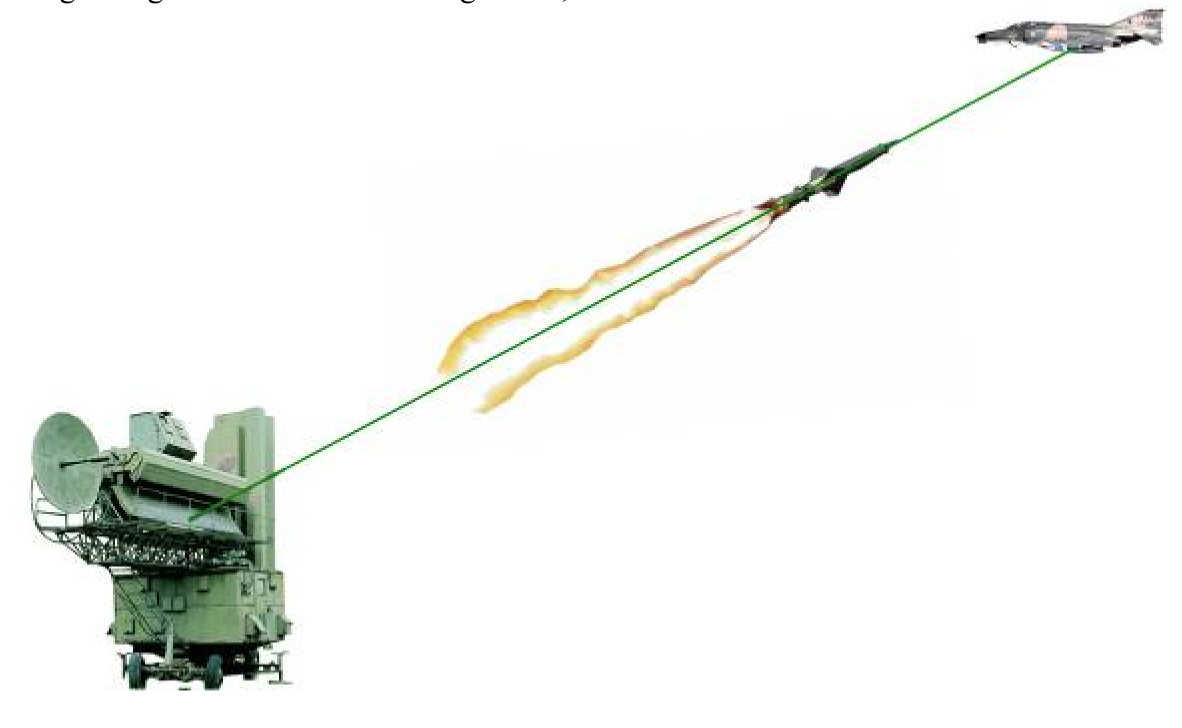
Shooting in this case is similar to a non-jamming target.
The burn through range is depending on the target size:

Against fighter-sized targets: 5 ~ 10km
Against bomber-sized targets: 10 ~ 20km

Preparations for Shooting at Noise Jamming Targets

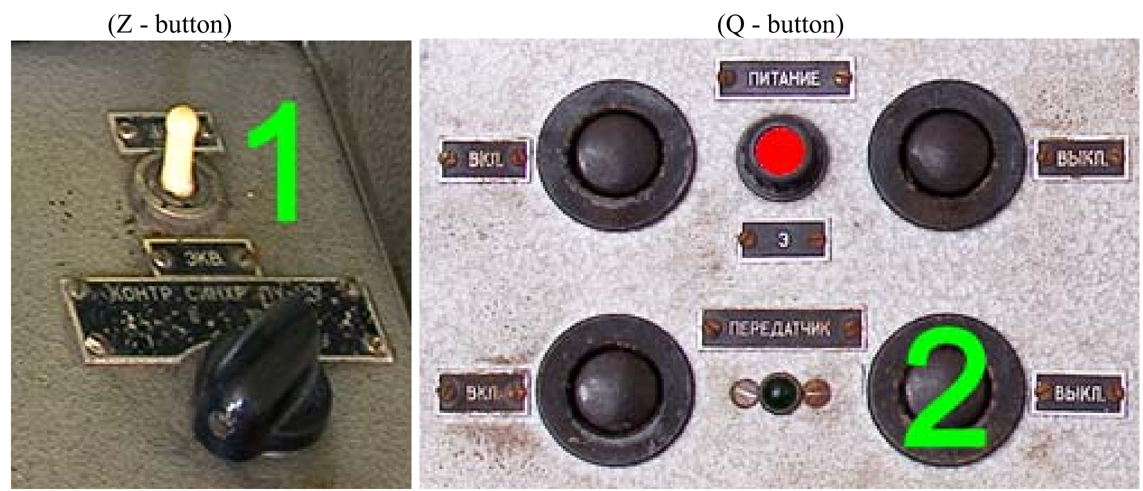
Missile guidance with (TT) "Three-point" method

Against noise jamming targets, we use the **T/T** "three-point" guidance method. Three-point guidance gets its name from the fact that the radar, missile and target are always lined up like three points on a straight line. In this mode the missile is always flying directly at the jamming target all the time.
Target range can be estimated using charts, with measured elevation.



Shooting on noise jamming target

(Z - button) (Q - button)



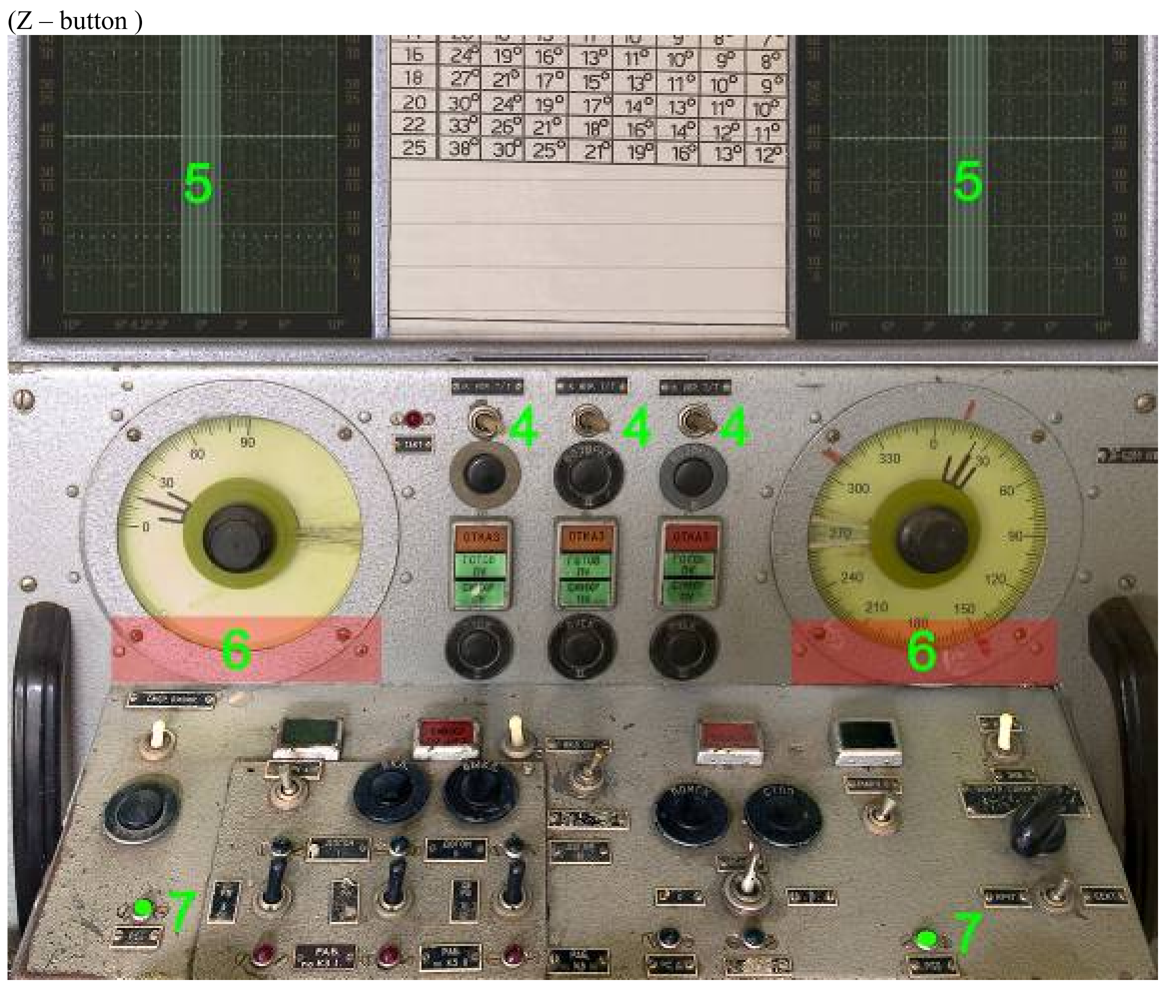
Tracking of noise jamming targets could be done in passive mode, where the antenna receiver is open (1), but the transmitter is turned off (2). Because the radar is not emitting it cannot be detected by electronic countermeasures and SIGINT receivers.

(Q - button)



3. Rotate the selector to 11sec (second setting from the right), and the **11 CEK.** (arm the missile radio proximity fuse 11s after launch) lamp will illuminate.

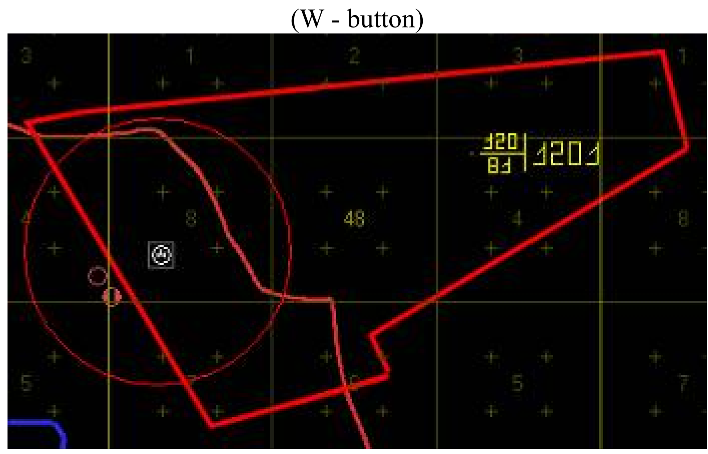
(Z – button)



4. Select **T/T**, for the “Three-point” guidance method (rightmost setting). In this mode the missile is always flying directly at the target.

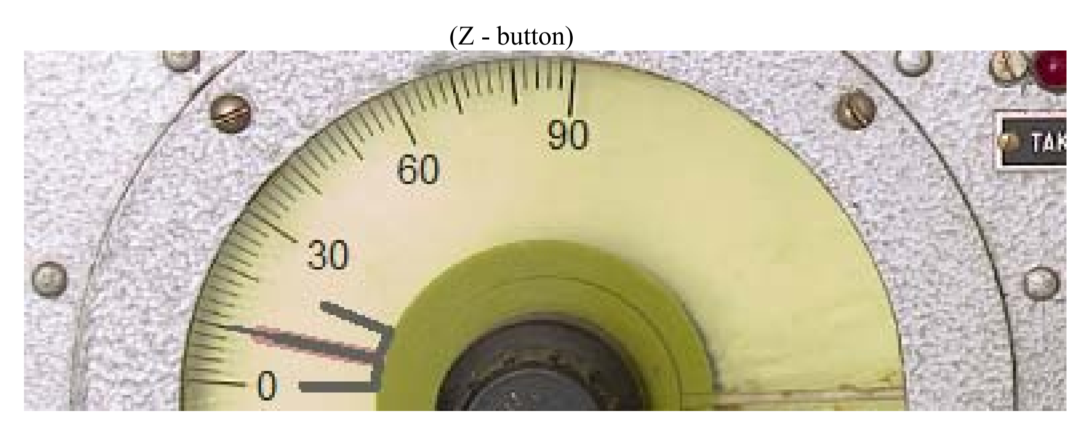
If the bore sight touches the vertical noise band (5), we can click with the right mouse button in the red area (6), and the target goes into automatic tracking in elevation and azimuth. The PCε, PCβ (target is in automatic tracking in elevation, azimuth) lamps are illuminated (7).

(W - button)



Jamming target altitude could be read off from the plotting chart. H=12km.

(Z - button)



Jamming target measured elevation could be read off from the elevation indicator ε=10°

(A - button)

H(km) \ D(km)	40	50	60	70	80	90	110	120
4	6°	4°	4°	[illegible]	3°	2°	2°	2°
6	9°	7°	6°	5°	4°	4°	3°	3°
8	11°	9°	8°	7°	6°	5°	4°	4°
10	14°	11°	10°	8°	7°	6°	5°	5°
12	17°	14°	[illegible]	10°	9°	8°	7°	6°
14	20°	16°	13°	11°	10°	9°	8°	7°
16	24°	19°	16°	13°	11°	10°	9°	8°
18	27°	21°	17°	15°	13°	11°	10°	9°
20	30°	24°	19°	17°	14°	13°	11°	10°
22	33°	26°	21°	18°	16°	14°	12°	11°
25	38°	30°	25°	21°	19°	16°	13°	12°

By using the table, we can estimate the jamming target distance…
… 12km altitude with 10° elevation is 70km range.

Now the calculated distance of the jamming target should be set with the range bore sight, and it could be engaged as if it would be a normal target.

Anti Radiation Missile (ARM)

ARM's, deployed since the 1960s, guide themselves to the microwave energy emitted by radars. As these missiles are visible in the radar screens, like fast approaching targets, the best defense against them is to turn the radar off in time.

Texas Instruments AGM-45 Shrike

The first fielded ARM, had significant limitations.



Fielded: 1963
Speed: 1.5Mach
Maximum Range: 45km
Length: 3.14m
Diameter: 20.3cm
Weight: 176kg
Warhead weight: 53kg

General Dynamics AGM-78 Standard ARM

The second ARM the US fielded, developed from the RIM-66 ship borne SAM. Provided increased speed, range and tactical flexibility.



Fielded: 1968
Speed: 1.8Mach
Maximum Range: 120km
Length: 4.2m
Diameter: 38cm
Weight: 589kg
Warhead weight: 100kg

Raytheon AGM-88 HARM

The state of the art ARM, it replaced the former types.



Fielded: 1982
Speed: 2,1Mach
Maximum Range: 150km
Length: 4,2m
Diameter: 25cm
Weight: 363kg
Warhead weight: 65kg